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Official Publication of the
National Aeronautics and
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March 1994 Vol. 18 No. 3

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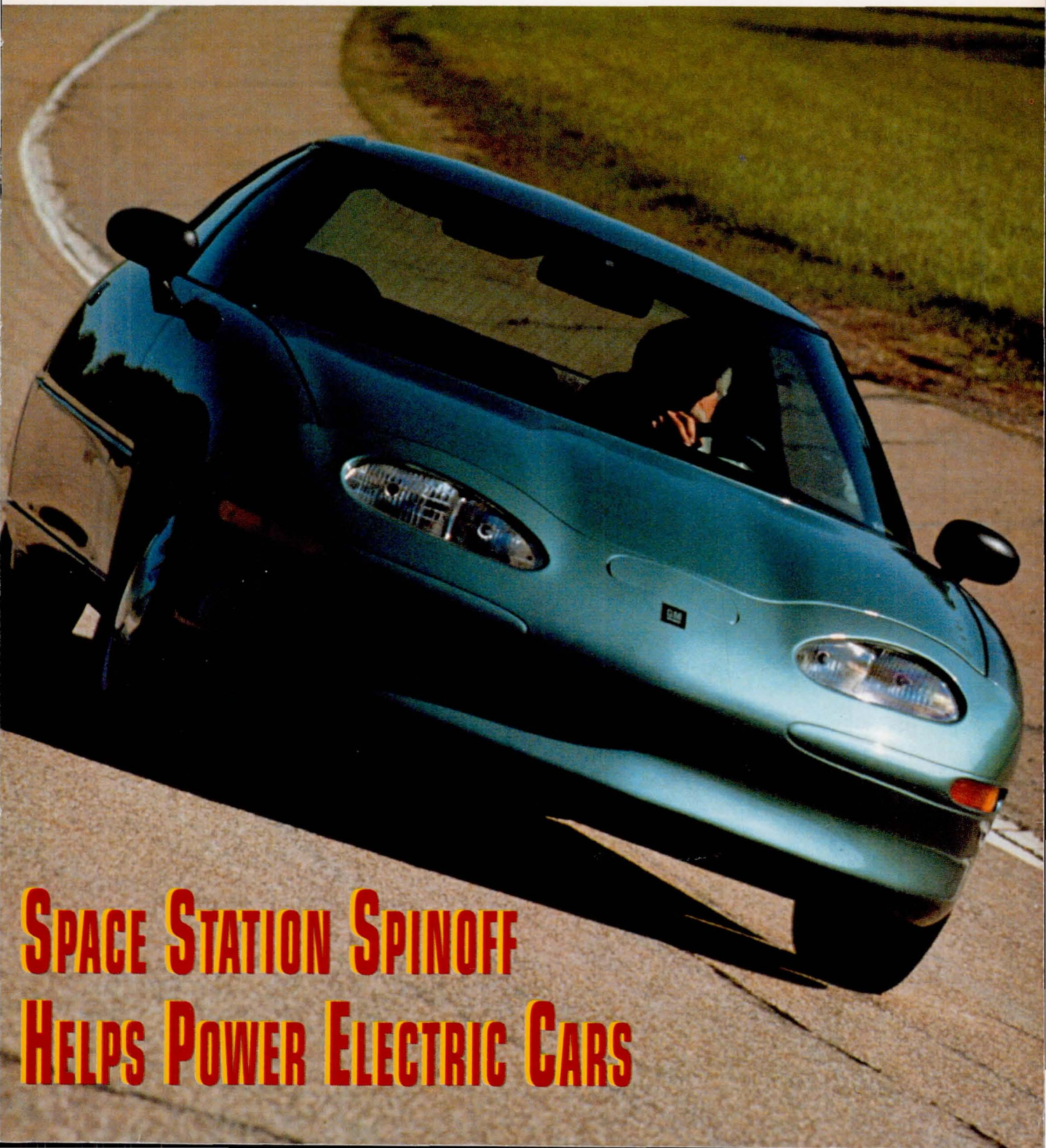
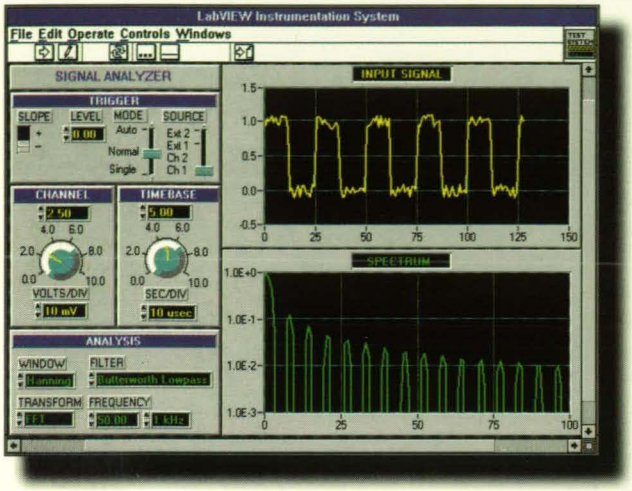
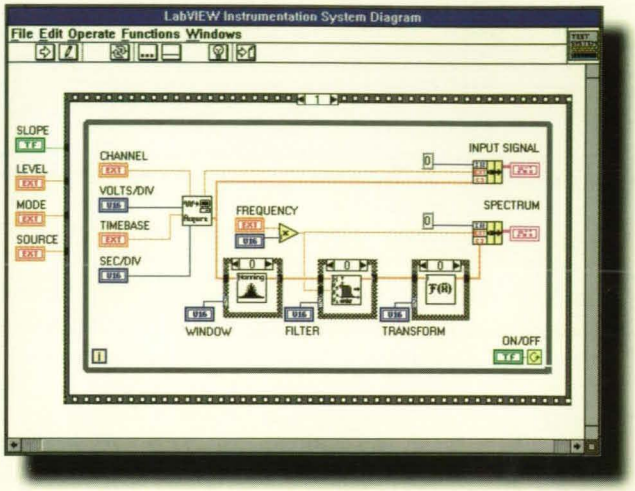


SPACE STATION SPINOFF HELPS POWER ELECTRIC CARS

More than Just Ease of Use ...





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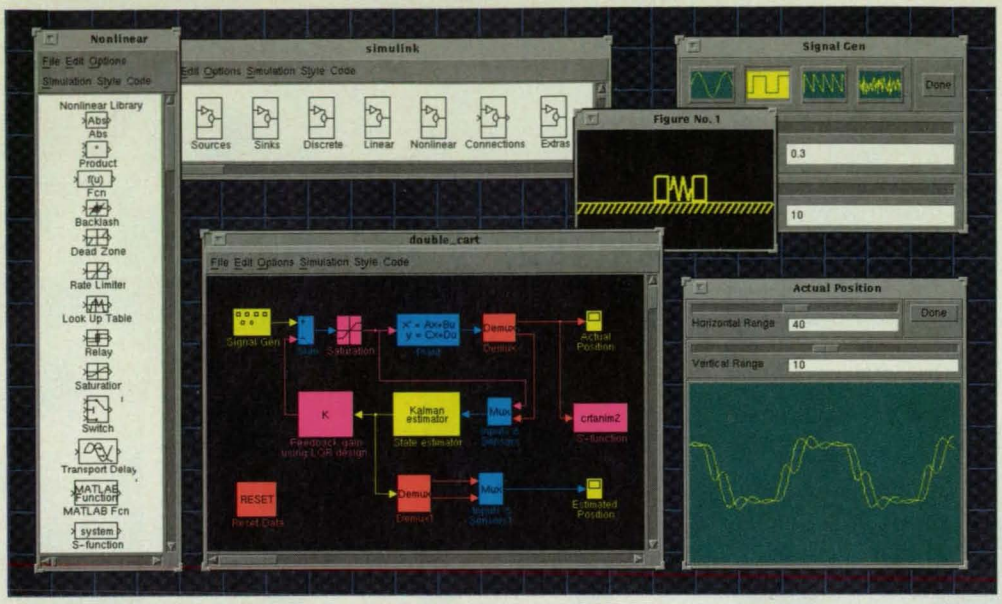


Simulating a system with SIMULINK: Scope block and MATLAB animation window show results while the simulation is running. You can change parameters during a simulation to do "what if" analyses.

It's time to go nonlinear with SIMULINK®.

SIMULINK gives you a powerful interactive workbench to model, analyze, and simulate physical and mathematical systems. SIMULINK allows you to rapidly model the behavior of complex systems like regional power grids, satellite controllers, aircraft, robotic systems and biochemical processes.

Create models graphically

With SIMULINK you can model a dynamic system quickly and easily. Just drag and drop icons into block diagrams — there's no need to write a single line of code.

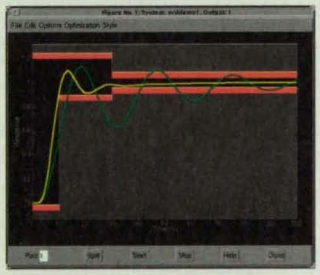
SIMULINK provides over 200 built-in block types from which to build your models. You can also design your own blocks, complete with custom icons. Plus, blocks can be grouped to create a model hierarchy.

Extensive model types

To model a complete range of system behaviors, you can combine linear and nonlinear elements defined in discrete-time, continuous-time or as a hybrid system.

Interactive simulation

SIMULINK makes it easy to run simulations and monitor results interactively. Just attach signal source blocks to generate input signals and oscilloscope blocks to monitor outputs. For "what if" analyses, change parameter settings while the simulation is running; you see the changed outputs immediately.



Graphically tune parameters in a nonlinear system with the Nonlinear Control Design Toolbox.

An open architecture

Because SIMULINK is based on the open and extensible architecture of MATLAB®, you can easily create blocks, customize existing blocks, build custom block libraries, and use MATLAB's toolboxes including:

- *Signal Processing*
- *System Identification*
- *Control System Design*
- *Robust Control*
- *μ-Analysis and Synthesis*
- *Neural Network*
- *Optimization*
- *Nonlinear Control Design*

New toolboxes for nonlinear optimization and real-time code

The new Nonlinear Control Design Toolbox automatically optimizes controller parameters using nonlinear simulation results..

SIMULINK's new C Code Generator lets you automatically generate real-time code from models, for embedded control, rapid prototyping, and standalone simulations on your target hardware or on DSP hardware.

SIMULINK Highlights

Modeling Tools

- *Block Library with 200+ blocks*
- *Custom blocks and libraries*
- *Custom icon editor*
- *Differential equations*
- *Linear and nonlinear*
- *Discrete-time, continuous-time, and hybrid*
- *Multi-input-multi-output*
- *Hierarchical modeling*
- *Write equations in Fortran, C or MATLAB*

Simulation and Analysis

- *7 integration methods for fixed, variable-step and stiff systems*
- *Interactive simulations with live displays*
- *Batch simulations from MATLAB command line*
- *Monte Carlo simulations*
- *Access to MATLAB's extensive toolboxes*
- *Trimming: determine stable equilibrium points*
- *Linearization*

SIMULINK is available on most popular computers, including Unix workstations, MS-Windows-based personal computers, and the Macintosh.

Call 508/653-1415 for a complete brochure.

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This full-featured cassette machine costs about half of what you'd expect to pay for such impressive specifications.

Plus, the new Metrum BVLDS is virtually maintenance-free. Needs no calibration or head cleaning. Takes only seven inches of rack space. And uses compact, economical ST-120 cassettes, which can save you a lot in storage hassles and media costs.

The BVLDS also comes with a parallel, serial or SCSI interface.

All things considered, it's hard to say what this unique machine's best feature is.

But its low price is a great place to start.

METRUM

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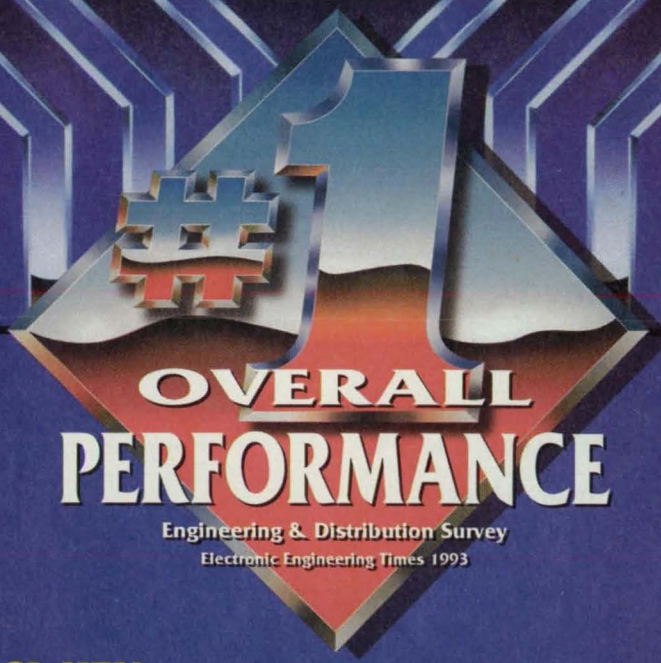

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In a recent "Engineering & Distribution Survey" conducted by *Electronic Engineering Times*, respondents were asked to evaluate distributors with whom they have done business or were most familiar. The table above reflects the percentage of respondents who rated these distributors as excellent (6&5 responses) on a 6 point scale where 6=excellent and 1=poor in terms of OVERALL PERFORMANCE!

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March 1994
Volume 18 Number 3

Contents

NASA Tech Briefs
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FEATURES

TECHNICAL SECTION

To Backup 50 GB, Two Heads Are Better Than One.

Single:
Drives can operate independently.

Cascade:
Data automatically writes to the second tape when the first tape is full.

Mirroring:
Writes the same data to both tapes simultaneously.

Striping:
Writes data to two tapes at once, in alternate blocks, doubling capacity and speed.

Introducing the dual drive CY-8505 with the Advanced SCSI Processor.

Working independently, each drive can store up to 25 GB, at speeds of up to 90 MB per minute. So it's perfect for unattended backup.

But performance *really* hits the ceiling when the drives *work together*.

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Each tape drive offers the most advanced in data recording technology. Our *hardware data compression* option is the fastest available. And it's switch-selectable, so you can read and write uncompressed data for compatibility with other sites. Add *accelerated file access* to locate a single file in an average of 85 seconds. And we even offer a *data encryption* option that lets you control access to sensitive data.

All this, and the *proven* reliability and price performance of 8mm helical scan tape storage.

We back this turnkey solution with a *two year warranty* that includes responsive service and technical support from our in-house engineering group.

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AT&T	DEC HSC	IBM RISC/	Douglas	PC 386/ix	Sequent	Unisys
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Designing Electrical Comp Edge Is Easy If You're

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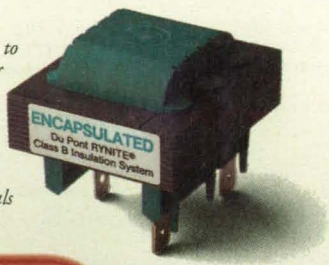
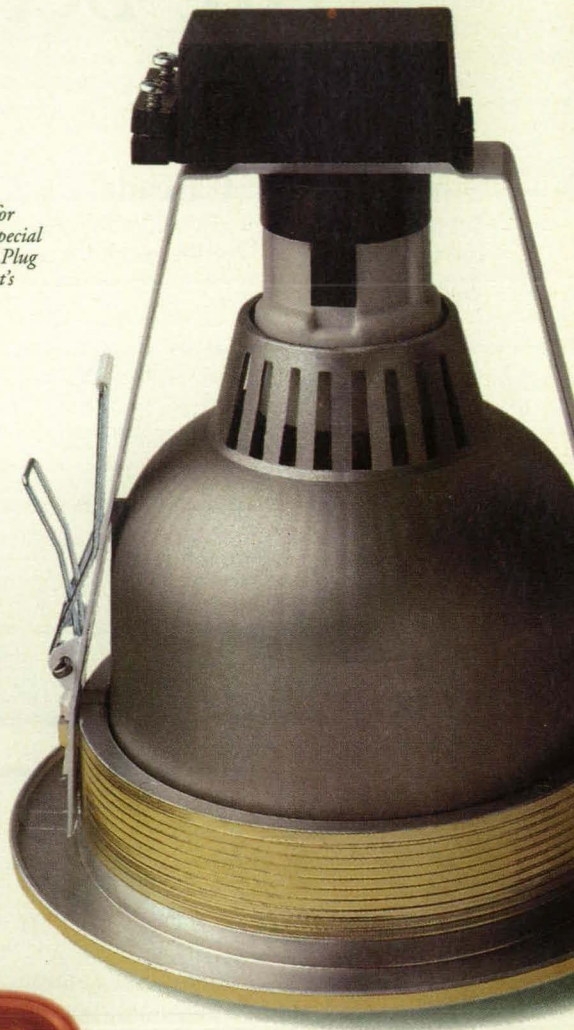


RYNITE® FR530 was chosen to encapsulate this transformer because it has a UL 94-V0 flammability rating and has UL 1446 Class B (130°C) insulation system recognition. Encapsulation provides molded-in terminals for easy plug-in installation.



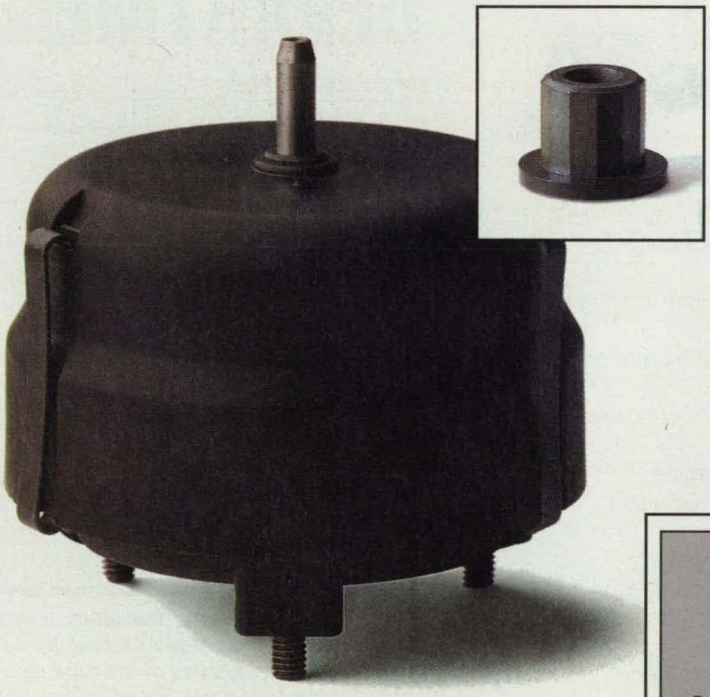
This down light's vacuum-metallized reflector and bezel of color-stable, high-temperature RYNITE® resists discoloration high temperatures. The retainer and terminal housing are of durable ZYTEL® for snap-fit resiliency.

RYNITE® FR530 is ideal for this unique motor stator because it's strong and stiff, is compatible with bondable wire processes, and offers UL 1446 Class F recognition. NOMEX® aramid insulation is used between the coils and core metal to meet high temperature requirements.

Whether you're redesigning electrical parts or creating new ones, plug into DuPont Engineering Polymers. Our wide range of high-quality materials will meet virtually any electrical materials challenge, from high temperature and dimensional stability, to better performance and durability, to simplified assembly, parts consolidation and reduced costs.

onents With A Competitive Plugged Into Du Pont.

This ballast case uses RYNITE® FR515 thermoplastic polyester resin because it offers a UL 94-5V rating and a 140°C RTI along with exceptional impact and tensile strength. With RYNITE,® potting isn't needed.



This fan motor for supermarket freezers features lubrication-free VESPEL® polyimide bearings in housings molded from new heat-dissipating RYNITE® CR (conductive resin). The stator is insulated with UL-recognized ZYTEL® nylon resin.

This plug uses crush- and chemical-resistant ZYTEL® to meet UL flammability and hospital requirements.

You can also call on DuPont for design and production assistance as well as pre-approved UL system recognitions that can save you time and money by eliminating testing. See how DuPont Engineering Polymers gave the electrical components shown here a competitive edge. Then call and let DuPont spark a few ideas.

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2301 Fluorescent Ballast
2401 Power Supply Transformer
2501 Brushless DC Motor

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For More Information Write In No. 618

Contents *(continued)*

Researchers at Jet Propulsion Laboratory have created a system to remotely control robotic land vehicles that requires only a small radio communication bandwidth. Twin cameras on the vehicle send occasional stereoscopic terrain images to an operator, who can plot a path by use of a cursor on the frozen image. The vehicle can be controlled despite transmission delay and intermittant availability of the communication bandwidth, conditions encountered during planetary exploration, military surveillance, firefighting, and hazardous waste removal. See the tech brief on page 50.

Photo courtesy Jet Propulsion Laboratory

DEPARTMENTS

On the cover:

High-power direct current contactors originally developed for the space station's electrical power system play a key role in the propulsion system of the Impact, General Motors' new electric car. The contactors, manufactured by Kilovac Corp., Santa Barbara, CA, enable the zero-emission Impact to travel safely at speeds up to 80 mph, with a 0-60 mph acceleration of 8.5 seconds. Turn to Mission Accomplished, page 14.

Photo courtesy General Motors Corporation

Errata: In the February issue, the article entitled "Measuring Frequency Instability of a Large Antenna" contained the following errors: in the first sentence of the third column on page 46, 2×10^{-5} should have read 2×10^{-15}; and in the first sentence of the second paragraph on page 48, 1.1×10^{-6} should have read 1.1×10^{-16}.

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SCIENCE/SCOPE®

Advanced Land Remote Sensing System's concept definition studies will address a broad spectrum of remote sensing approaches into the next century. For nearly thirty years imaging sensors built by Hughes Aircraft Company have observed Earth from space, collecting more than three million images. Hughes' decades of experience in space-based remote sensing, communications, ground processing, and data exploitation for the national security, civil and commercial markets will continue to benefit the remote sensing and geographic information systems communities. Space-based remote sensors have proven to be an invaluable tool in monitoring day-to-day weather, environmental trends and global change research; management of water and agricultural resources; and land use planning. Hughes sensors have provided detailed imagery and data on natural and man-made disasters, including the recent flooding in the Midwest, deforestation of the rain forests, the nuclear accident at Chernobyl, the oil spill in the Persian Gulf, and the oil well fires in Kuwait. Today, national security, civil, scientific, and commercial mission requirements are being synergistically met with Hughes' broad operational expertise.

Hughes has developed a steam injection technology that can uniquely treat diesel fuel, jet fuel, kerosene, and other heavy hydrocarbons in place. At the right temperatures and pressures, it forces hydrocarbons to migrate to extraction wells, where they are safely extracted for treatment. This in-place method of removing and treating hydrocarbons without excavating the soil is nonobtrusive, and saves both time and money.

A new magnetic sensor developed by Hughes will help improve the performance of General Motors cars. This crankshaft positioned detector device provides precise ignition firing timing, resulting in fuel savings, better mileage, and reduced emissions. Initially, the sensor will be used in 1995 GM truck engines, with production expected to reach two million units per year by 1996. Hughes has become committed to automotive electronics, supplying both sensors and integrated circuits for engine control and dashboard instrumentation. They are also applying their advanced sensor technology to anti-lock brakes, brushless motor commutation sensors, and transmission speed sensors.

Thailand will have its first domestic communications satellite system in 1993. Hughes will provide Bangkok's Shinawatra Computer Company with two HS 376 spin-stabilized satellites, as well as ground equipment and training support. These new spacecraft will be smaller, lighter-weight versions of the standard HS 376. Hughes' spacecraft have helped many countries establish commercial communications services, beginning with Canada in 1972.

The first in a new generation of cable television satellites, Hughes' Galaxy V is providing video transmission services for leading cable networks, including CNN, HBO, ESPN, and The Disney Channel. This Hughes-built satellite, which is positioned 22,300 miles above the equator, is the most advanced cable-dedicated satellite in orbit today. With higher power and longer life than its predecessors, Galaxy V will provide service to the cable TV industry well into the 21st century.

For more information write to: P.O. Box 80032, Los Angeles, CA 90080-0032

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The Apple Report On PowerPC

Number 2 – RISC Performance and Cross-Platform Compatibility

Many of the most popular applications have been or are being optimized to take advantage of the high-performance PowerPC processor.

PowerPC chips are faster and less expensive than Pentium chips – so are the personal computers they will run.

A complete Macintosh system with PowerPC will cost well under $2,500, but will offer better performance than higher-priced Pentium-based systems.

With SoftWindows, Macintosh with PowerPC will have the ability to run DOS and Windows applications, unmodified.

For more information about Macintosh with PowerPC, call 1-800-732-3131, ext. 150, in the U.S. We'll send you a copy of our informative, free booklet, *PowerPC Technology: The Power Behind the Next Generation of Macintosh Systems*. In Canada, call 1-800-665-2775, ext. 910.

In the first half of 1994, Apple will introduce a new family of computers that already has the entire computer industry standing on end.

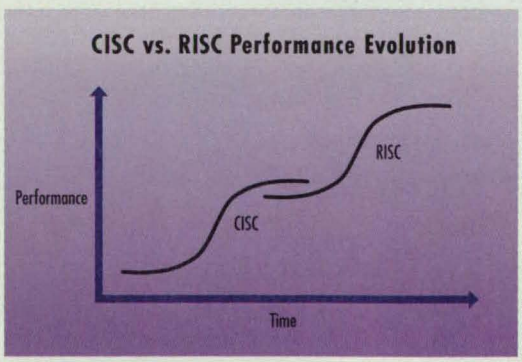
They will offer better performance than computers based on the X86 microprocessors. They will be extremely competitive on a price basis. And they will be compatible with Windows and DOS applications, by using SoftWindows software.

They will be based on the revolutionary new PowerPC™ microprocessor, created jointly by Apple, IBM and Motorola.

For the first time, desktop personal computers will take advantage of RISC chip architecture previously found only in high-performance workstations. This advance will make possible quantum improvements in the way we manage and work with information.

RISC vs. CISC.

Tremendous advances have been made in CISC architecture over the years. However, the physical limitations of the new, high-performance CISC design mean that CISC chips must be significantly bigger and more complex, and must run at hotter temperatures to perform the same tasks as comparable RISC chips. Consequently, the newer generation of CISC chips, like the Pentium, are much more expensive to manufacture. Which means that personal computers powered by PowerPC chips can offer a significant advantage in price as well as in performance.



As you can see on the chart, RISC microprocessors offer dramatically greater potential for growth, leading us well into the next century and increasing the practicality of features like voice recognition, videoconferencing, object-oriented software and multimedia capabilities – functions that will be integral to doing business in the 21st century.

More compatible personal computers.

Apple's new generation of Macintosh® personal computers built around the PowerPC chip offer the ability to run MS-DOS and Windows applications, as well as Macintosh software. Moving from one environment to the next will be seamless and, even more importantly, it will be effortless.

PC users who move to Macintosh with PowerPC will gain access to the large number of new applications which take advantage of the incredible performance of the new PowerPC chip.

Higher-performance optimized applications.

When PowerPC microprocessor-equipped Macintosh computers begin shipping, software developers including Microsoft, WordPerfect, Adobe, Aldus and Claris will begin shipping new versions of their most popular software, specifically rewritten to take full advantage of the new processor's capabilities.

These optimized, sometimes called "native," applications will offer significantly faster performance than their MS-DOS, Windows or current Macintosh counterparts.

Unprecedented value.

Because RISC-based personal computers cost less to manufacture than equivalent systems based on CISC chips, we will be able to make this technology available for well under $2,500 for a complete mainstream desktop system.* Competitive with a lower-performance, Pentium-based PC.** Watch for Apple Report #3, coming soon.

Apple

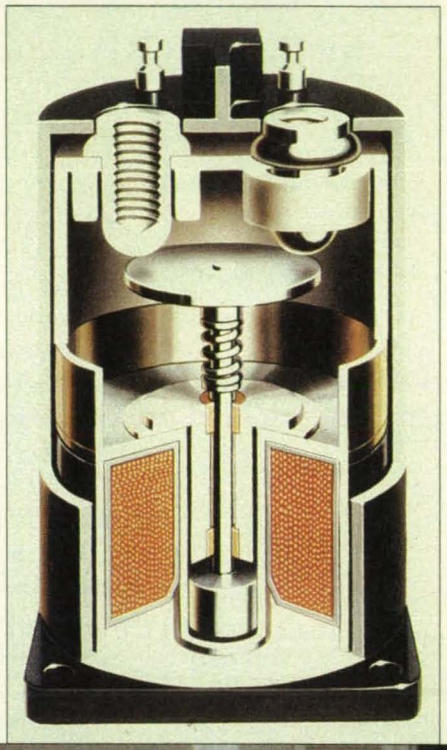
Mission Accomplished

Through the technology transfer process, many of the systems, methods, and products pioneered by NASA are reapplied in the private sector, obviating duplicate research and making a broad range of new products and services available to the public.

The drive to create consumer-friendly electric vehicles (EVs) depends upon battery technology, which must offer not only emission-free but efficient, safe, and far-reaching propulsion. A key component of many of the leading-edge battery systems powering today's most promising EVs is a contactor from Kilovac Corp., Santa Barbara, CA, originally developed to provide the main electrical power switch on NASA's space station.

The impetus behind the contactor's development came in 1989 when Rocketdyne began designing the space station's electrical power system, scheduled to be assembled in space beginning in 1997. Because the system will have to operate at very high power levels, Rocketdyne needed small, lightweight contactors that could reliably switch and interrupt high current at high voltages.

"The main thing that enabled us to win the Rocketdyne contract was our ability to demonstrate capability at high power levels in a small relay—other people can switch power like we can, but their devices are a lot bigger," said Stephen Perreira, senior engineer at Kilovac. "We were able to make leaps forward in size reduction because we use a nonconventional actuator mechanism; the whole moving mecha-



The cutaway at right illustrates a direct current contactor originally developed for the space station's electrical power system that now serves in today's most advanced electric vehicles.

Below: the two-seater Impact, General Motors' new electric car, which offers a city/highway range of 70/90 miles, 0-60 mph acceleration of 8.5 seconds, and a top speed of 80 mph. A two-year field test beginning this spring will afford 1000 customers nationwide the opportunity to test drive the Impact.

The Delta Clipper Experimental DC-X.

THE NEXT BREAKTHROUGH IS YOURS.

Some people called McDonnell Douglas Aerospace's mission "unthinkable": develop a prototype reusable single-stage rocket vehicle in less than two years. And do it on a budget that was unthinkably tight.

But only eighteen months later and under budget, McDonnell Douglas' Guidance Navigation and Control Group delivered flight control software for the Delta Clipper Experimental rocket. On its first flight on August 18, 1993, the autonomously controlled DC-X performed flawlessly, taking off and landing vertically, right on target.

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nism is within the vacuum switch assembly, which results in very high reliability and long electrical life."

The resulting product became known as the Czonka contactor, a 270 VDC vacuum contactor with a 150 A continuous carry and 500 A overload rating. Based on the success of the Czonka, Kilovac was awarded another space station contract for what eventually would become the Bubba contactor. It can make and break 350 A and carry 500 A with an overload rating of 1500 A at 320 VDC.

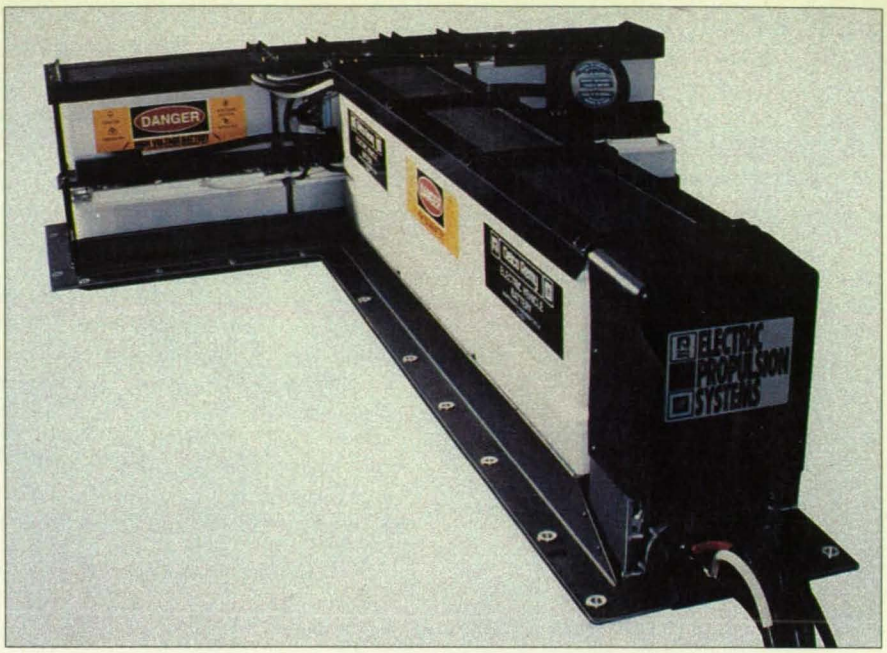
Switching high-voltage DC loads is one of a contactor's toughest jobs. The contactor has two parts: one that opens and closes the contacts and a means to control the arc that occurs between the contacts when power is switched. Kilovac developed techniques to control and manage these arcs, ensuring that unbreakable welds don't form, that contact erosion is limited, and that even at high overload ratings the arc always is extinguished.

"The basic form of the Bubba relay was the big breakthrough that drove our technology into commercial viability," said Perreira. "The first Rocketdyne contract allowed us to develop a highly reliable internal moving mechanism, then with Bubba we were able to develop an improved arc control mechanism."

Electric vehicle manufacturers took notice. The same characteristics that qualify the contactors for space application make them useful in EVs: small size, light weight, low power consumption, high overload capability, bi-directional switching, and a sealed switching chamber.

By 1990, the push was on to create commercial-grade electric vehicles to meet California's new Zero Emission Vehicle initiative. The law requires that starting in late 1997 (model year 1998), two percent of all cars sold in California must be zero emission vehicles. To date, 11 other states have adopted the initiative.

The Delco Remy Division of General Motors (GM) selected the Czonka for use in the 312 V, 16.8 kW-hour battery pack that powers the Impact, GM's new electric car. The contactor serves as a disconnect that automatically isolates the batteries in the event of an electrical problem.



The Delco Remy Division of General Motors developed this T-shaped battery pack for the Impact, incorporating 26 serially-connected 12 V gas recombinant lead-acid battery cells to power the car's 137-horsepower AC induction electric motor. The pack employs Kilovac's Czonka contactors as automatic safety disconnects.

The Impact's battery pack employs 27 valve-regulated 12 V gas recombinant lead-acid battery cells arranged both longitudinally down the center of the car and laterally behind the wheels. This layout conserves interior space while making the battery pack a structural component of the car. Twenty-six of the cells supply power to its front-drive 137-horsepower (102 kW), liquid-cooled AC induction electric motor, enabling the two-seater Impact to travel from 0 to 60 mph in 8.5 seconds with a top speed of 80 mph. The remaining cell powers onboard accessories including steering, braking, heating and air conditioning, and displays.

To make the Impact practical for consumers, a charge port built into the car's nose accepts a magnetic inductive coupler, which eliminates exposed contacts and connects to a home's 220 V electrical system or 110 V household outlet. Fully charged in two to three hours, the battery pack provides the energy equivalent of 1.5 gallons of gasoline for a range of 70-90 miles. Charging will cost consumers approximately one penny per mile.

Starting in April, GM, in partnership with a number of electric utilities, will provide 1000 households in 12 cities nationwide the opportunity to test drive one of 50 limited-production Impacts. The planned two-year "PrEView" is intended to encourage development of the service and charging infrastructure needed to support EVs, demonstrate EV technology, and obtain feedback from potential customers about the car's performance.

The Kilovac contactors have found application in other electric vehicles including buses and boats. The Czonka contactors are part of the battery module used by US Electricar, Sebastopol, CA, to convert Geo Prizms and Chevrolet S-10 pickup trucks into EVs, 200 of which are currently on the road.

Ed Rannburg of Fontana, CA, is counting on three Bubba contactors to help him set a new world EV land speed record this summer. His vehicle, called the Lightning Rod, is expected to exceed 200 mph, well over the current record of 175 mph set in 1974.

Additionally, the contactors can be applied in a wide range of industrial applications, including backplane power for computers, utility and factory control power, light rail transit, distributed power systems, circuit protection, and transfer switching.

Incorporating technology developed during the Rocketdyne contract for the Bubba contactor, Kilovac recently introduced the Czonka II, which can make and break 250 A with a 1500 A overload rating. Currently serving as the main generator contact on the F22 fighter aircraft, the Czonka II is designed for use in the next generation of electric cars. ❑

For more information about the technology discussed above, contact Pat McPherson, Vice President of Sales and Marketing, Kilovac Corp., P.O. Box 4422, Santa Barbara, CA 93140. Tel: 805-684-4560; Fax: 805-684-9679.

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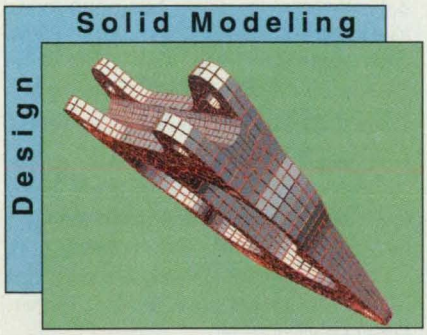
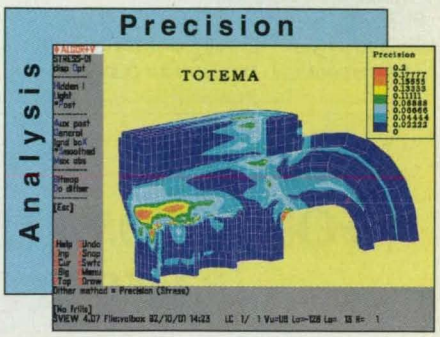


Model courtesy of Mercruiser Stern Drives and Inboards, Stillwater, OK, U.S.A.

Model courtesy of Italmagnésio Sao Paulo, Brazil.



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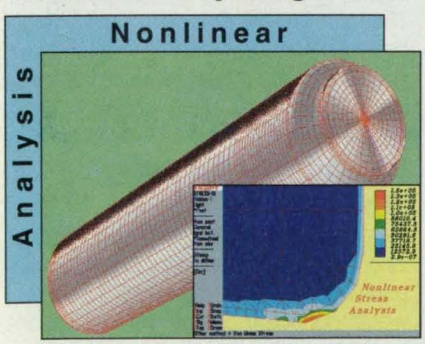
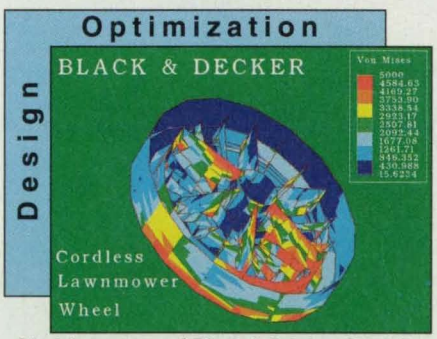


Model courtesy of West Valley Nuclear Services Co., West Valley, NY, U.S.A.



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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Stationary Camera Aims and Zooms Electronically

A video camera pans, tilts, zooms, and provides rotations of images of objects of its field of view, all without moving parts. The camera can be used for surveillance, for closeup tracking of multiple objects in the field of view, or to break an image into sectors for simultaneous viewing, thereby replacing several cameras.
(See page 46.)

Low-Toxicity PMR Polyimide

A new, low-toxicity PMR system has been developed. This system incorporates 3,4′-oxydianiline, which has been found to exhibit no detectable mutagenicity.
(See page 74.)

Lightweight Electrode for Nickel/Hydrogen Cell

An improved substrate for a nickel electrode increases the specific energy a nickel/hydrogen cell. The substrate consists of 50 percent by weight nickel fiber, 35 percent nickel powder, and 15 percent cobalt powder.
(See page 72.)

Synthesis of Perfluoro Orthocarbonates

They might be useful as heat-exchange fluids, lubricants, and/or vapor-phase soldering fluids.
(See page 80.)

Acetylene- and Phenylacetylene-Terminated Poly(Arylene Ether Benzimidazole)s (PAEBI's)

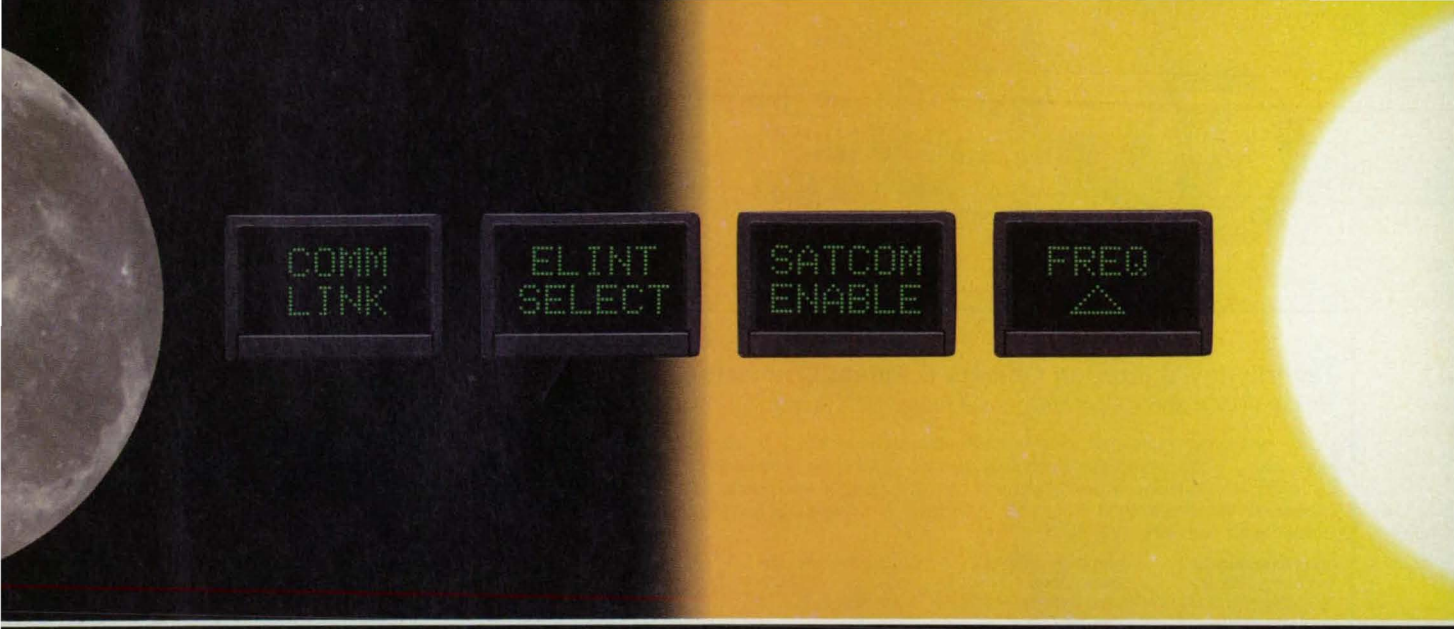
These polymers exhibit excellent adhesion to copper foil and polyimide film. The materials are potentially useful as adhesives, coatings, composite matrices, fibers, films, membranes, and moldings.
(See page 76.)

Latching Solenoid-Operated Ball Valve

A proposed ball valve would latch in its open or closed position until it is energized to change position. The valve would consume energy only during the switching interval, which would last no more than 40 ms.
(See page 97.)

Improved All-Terrain Suspension System

A new suspension system for an all-terrain vehicle exhibits enhanced ability to negotiate sand and rocks. The suspension has potential application in off-road vehicles and toys.
(See page 97.)



The NVIS-Sunlight Readable Interactive Switch System.

The VIVISUN 5000 interactive switch system incorporates LED lighting that is both NVIS compatible and sunlight readable per MIL-L-85762A. This fully programmable system also provides rugged reliability and meets the environmental extremes that military programs demand.

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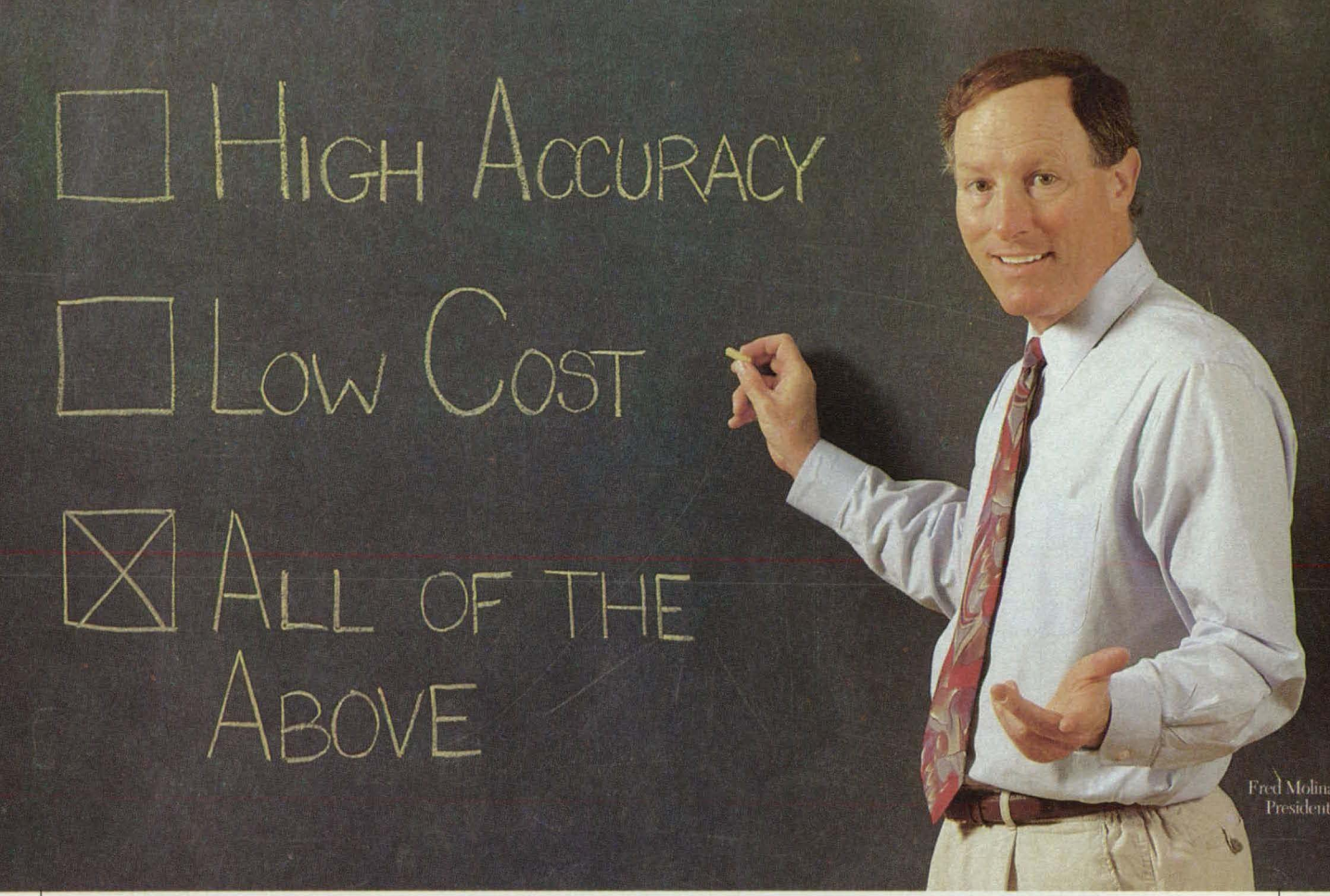

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RENT provides an organized, systematic collection of IBM features that consist of panels, clists, skeletons, and messages, along with FORTRAN and Pascal programs and example NASTRAN data files. A primary goal of RENT is to provide a user-friendly computing environment in which handling of files and operating-system considerations can be hidden from view of the average NASTRAN user. The NASTRAN user can build and run their own finite-element model without concern for file allocations, procedures, and job-control languages. The environment is used for training as well as production level work.

The training module RENT is provided to instruct new users on many aspects of finite-element modeling by use of NASTRAN. This includes 18 problems (10 static, 8 dynamic) with classical solutions tailored to the sizes, properties, and loads chosen by the user. This enables individuals to learn at their own paces and to verify the accuracies of the models they build. A special feature of RENT is the extensive on-line COSMIC NASTRAN documentation available. This on-line manual provides instant information on the NASTRAN executive, case and bulk data cards, rigid formats, Direct Matrix Abstraction Program (DMAP) listings, and error messages. Also included is a NASTRAN dictionary.

RENT is written in VS/FORTRAN, VS/ Pascal, and IBM job-control language for an IBM computer system running MVS/ ESA SP 4.1.0 using TSO/E 2.1.0. Executable code is included. The VS/FORTRAN and VS/Pascal compilers are required to produce new executable code. RENT has job setups to execute COSMIC/NASTRAN and MSC/NASTRAN on an IBM computer or MSC/NASTRAN on the CRAY computer running UNICOS 6.1. At least one of these versions of NASTRAN is required to run RENT as intended. RENT includes over 80,000 lines of online NASTRAN documentation. The standard distribution medium for this program is a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape in IEBCOPY format. A 5.25-in. (13.34-cm), 360K diskette in MS-DOS format containing installation files is also included. A 36-page System Manual accompanies this software. The Rockwell Environment and NASTRAN Trainer was released in 1991.

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This program was written by H. R. Grooms, P. J. Hinz, M. A. Collier, Kim D. Cox, Warren J. Merriman, and Gerry Commerford of Rockwell International Corp., for **Johnson Space Center**. *For further information,* ***write in 47*** *on the TSP Request Card.*

MSC-22092

Analyzing Seals With Two-Phase Flows

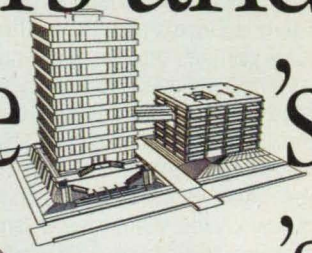
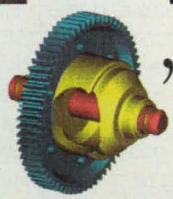
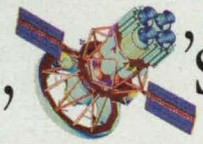
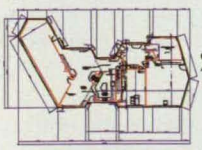
Performances of face and annular seals are computed from idealized mathematical models.

When liquid is sealed at a temperature higher than its saturation temperature at the outlet pressure, it flashes inside the seal because of the pressure drop and/ or the viscous dissipation of heat. Typical examples of fluids and situations in which such two-phase flow may be encountered include light hydrocarbons in petroleum refineries, hot water in boiler-feed and reactor-coolant pumps, and cryogenic fluids like liquid oxygen and hydrogen in rocket turbopumps. The SEAL computer program analyzes the steady-state performance of a face seal with two-phase leakage flow operating under both low-leakage laminar and high-leakage turbulent flows. The mathematical models used in the analysis are the quasi-isothermal model when the leakage flow is small and laminar, and the adiabatic turbulent model when the leakage is large and turbulent.

SEAL calculates the general trends of performance of face seals under both low- and high-leakage conditions and, by extrapolation, behavior in the intermediate region. Parameters that can be investigated include subcooling, coning of seal faces, speeds of rotation, conductivities of seal materials, and widths of seal faces. The program incorporates idealized mathematical models, and is based on a finite-difference approach.

SEAL is written in FORTRAN 77 for IBM PC-series computers and compatibles running MS-DOS. The executable code included on the SEAL diskette was created by use of Microsoft FORTRAN v.3.3.1. Hardware requirements include an 80286 or 80386 processor

Yes,

you can do Windows™ and walls and doors and floors, ceilings, whole  's,  's, trains, boats,  's, chains,  's, diamond rings,  's and things,  's, power plants, topo maps,  's, helicopters, roads and bridges, circuit boards,  's power lines,  's, airports, furniture, digital terrain models,  's, skateboards, the  ,  's, chemical plants,  's, golf courses, anything you can think of ... even the kitchen  .

and a math coprocessor. The main memory required for execution is 137K. Sample input, output, and instructions on execution are included with this software package. The standard distribution medium for this package is a 5.25-in. (13.34-cm), 360K MS-DOS diskette. SEAL was developed in 1989.

MS-DOS is a registered trademark of Microsoft Corp. IBM PC is a registered trademark of International Business Machines Corp.

This program was written by S. Lau , P. A. Beatty, and William F. Hughes of Carnegie-Mellon University for **Lewis Research Center**. *For further information,* ***write in 19*** *on the TSP Request Card. LEW-15156*

Program Helps Design Composite Panels

PASCO assists in buckling and vibration analysis and in low-mass design.

The Panel Analysis and Sizing Code (PASCO) computer program was developed for the buckling and vibration analysis and sizing of prismatic structures that have arbitrary cross sections. PASCO is primarily intended for analyzing and sizing stiffened panels made of laminated orthotropic materials, and is of particular value in analyzing and sizing filamentary composite structures.

When used in the analysis mode, PASCO calculates stiffnesses of lamina and stresses and strains (including the effects of temperature and panel bending) in lamina, buckling loads, vibration frequencies, and overall stiffnesses of panels. When used in the sizing mode, PASCO adjusts sizing variables to provide a low-mass design for a panel that can carry a set of specified loads without exceeding buckling or other material-strength allowables and that meets such other design requirements as upper and lower bounds on sizing variables, upper and lower bounds on overall bending, extensional and shear stiffnesses, and lower bounds on vibration frequencies.

Although emphasis in PASCO is placed on flat panels that contain several identical bays, the only restriction on configuration modeling is that the structure is assumed to be prismatic. In addition, it is assumed that loads and temperatures do not vary along the length of a panel. PASCO is designed to handle readily the analysis and sizing of the stiffened panels that are used widely in aerospace structures. The cross section of a panel can be composed of an arbitrary assemblage of thin, flat, rectangular plate elements that are connected together along their longitudinal edges. Each plate element consists of a balanced symmetric laminate of any number of layers of orthotropic material. Any group of element widths, layer thicknesses, and layer-orientation angles can be selected as sizing variables. Substructuring is available to increase the efficiency of the analysis and to simplify the modeling of complicated structures.

The Macintosh version of PASCO includes an interactive, graphic preprocessor called MACPASCO. The main objective of MACPASCO is to make the use of PASCO faster, simpler, and less error-prone. By including a graphical user interface (GUI), MACPASCO simplifies the specification of panel geometry and reduces the incidence of user's input errors, thus making the modeling and analysis of panel designs more efficient. The user draws the initial structural geometry on the computer screen, then uses a combination of graphic and text inputs to refine the structural geometry, specify information needed for analysis (for example, panel load conditions), and define design variables and constraints for minimum-mass optimization. Design of composite panels is an ideal application because the graphical user interface can serve as a visual aid, eliminate the tedious aspects of text-based input, and eliminate many sources of input errors. The current version of MACPASCO does not implement all the modeling features of PASCO but has been found to be sufficient for many users.

Because MACPASCO includes a GUI, many difficulties common to text-based inputs are avoided. First, the graphical displays eliminate syntax errors, like misplaced commas and incorrect command names, because there is no text-based syntax. Second, graphical displays enable the user to see the geometry as it is created, thereby assisting the user in immediately detecting and correcting any errors. Third, the drawing software tools in MACPASCO have been designed to avoid modeling errors. Fourth, the graphical displays make revisions to existing structural designs much easier and less error-prone by eliminating the need for the user to conceptualize the text input as geometry: the user can work directly with the geometry displayed on the screen. Finally, MACPASCO automatically generates the correct PASCO input file from the geometry displayed on the screen. This input file can be used with any machine version of PASCO to perform the analysis and sizing and to display or transfer the rdesults.

The DEC VAX and CDC CYBER versions of PASCO are written in FORTRAN IV for batch execution and have been implemented on a DEC VAX and a CDC CYBER 170-series computer. The CYBER version requires a problem-dependent central memory of 120K (octal) of 60 bit words. The Macintosh version of PASCO was developed for Macintosh II-series computers with at least 2 Mb of random-access memory running MPW Pascal 3.0 and Language Systems FORTRAN 2.0 under the MPW programming environment. It includes MPW-compatible makefiles for compiling the source code. The Macintosh version uses input files compatible with versions of PASCO that run on different computers. MACPASCO is written in Macintosh Programmers Workbench 3.0, MPW Pascal 3.0, and MacAPP 2.0. The Pascal source code is included on the distribution diskette. MacAPP is a development library of software that is not included. MACPASCO requires a Mac Plus, SE/30, or MacII, IIx, IIcx, IIci, or IIfx computer running System 6.0 or greater. MACPASCO is compatible with System 7.0. A minimum of 2 Mb of random-access memory is needed for execution.

The Macintosh version of PASCO is distributed on four 3.5-in. (8.89-cm), 800K Macintosh-format diskettes. The CDC and DEC VAX versions are distributed on 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape. The PASCO program was developed in 1981, adapted to the DEC VAX in 1983, and to the Macintosh in 1991. MACPASCO was released in 1992.

This program was written by Stephen H. Lucas of Analytical Services and Materials, Inc., and Randall C. Davis of **Langley Research Center**. *For further information,* ***write in 54*** *on the TSP Request Card. LAR-14799*

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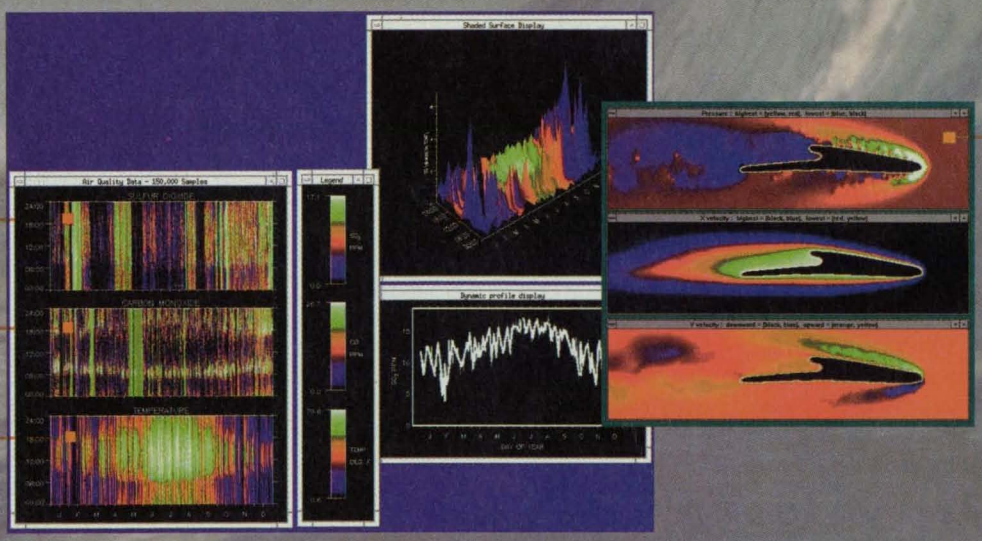

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For More Information Write In No. 537

Preprocessor Program for Use With PASCO

MACPASCO makes the specification of panel geometry easier and less error-prone.

MACPASCO is an interactive, graphical preprocessor program designed to make the use of the Panel Analysis and Sizing Code, PASCO, (COSMIC program numbers LAR-13004, LAR-13164, and LAR- 14799) faster, simpler, and less error-prone. PASCO is primarily intended for use in analyzing and sizing stiffened panels made of laminated orthotropic materials and is of particular value in analyzing and sizing filamentary composite structures. MACPASCO is a Macintosh-based preprocessor program that includes a graphical user interface (GUI) program to simplify the specification of panel geometry, thus making the modeling and analysis of panel designs more efficient and reducing the potential for user input errors. Although MACPASCO runs only on a Macintosh computer, output from MACPASCO can be used as input for any machine version of PASCO. For this reason, COSMIC offers MACPASCO (LAR-14908) as a separate package in addition to including it in the Macintosh version of PASCO (LAR-14799).

When one uses MACPASCO, one draws the initial structural geometry on the computer screen, then uses a combination of graphical and textual inputs to refine the structural geometry, specify information needed for analysis (for example, panel load conditions), and define design variables and constraints for minimum-mass optimization. Design of composite panels is an ideal application because the graphical user interface can serve as a visual aid, eliminate the tedious aspects of text-based input, and eliminate many sources of input errors. The current version of MACPASCO does not implement all the modeling features of PASCO but has been found to be sufficient for many users.

Because MACPASCO includes a GUI, many difficulties common to text-based inputs are avoided. First, the graphical displays eliminate syntax errors, like misplaced commas and incorrect command names, because there is no text-based syntax. Second, graphical displays enable the user to see the geometry as it is created, thereby assisting the user in immediately detecting and correcting any errors. Third, the drawing software tools in MACPASCO have been designed to avoid modeling errors. Fourth, the graphical display makes revisions to existing structural designs much easier and less error-prone by eliminating the need for the user to conceptualize the text input as geometry: the user can work directly with the geometry displayed on the screen. Finally, MACPASCO automatically generates the correct PASCO input file from the geometry displayed on the screen. This input file can be used with any machine version of PASCO to perform the analysis and sizing and to display or transfer the results.

MACPASCO is written in Macintosh Programmers Workbench 3.0, MPW Pascal 3.0, and MacAPP 2.0. A sample executable code is included on the distribution diskette. MacAPP is a development library of software that is not included. MACPASCO requires a Mac Plus, SE/30, or MacII, IIx, IIcx, IIci, or IIfx computer running System 6.0 or greater. MACPASCO is compatible with System 7.0. A minimum of 2 Mb of random-access memory is needed for execution. The standard distribution medium for MACPASCO is a set of two 3.5-in. (8.89-cm), 800K Macintosh-format diskettes. MACPASCO was released in 1992.

This program was written by Stephen H. Lucas of Analytical Services and Materials, Inc., and Randall C. Davis of **Langley Research Center**. *For further information,* ***write in 30*** *on the TSP Request Card. LAR-14908*

Integrated Composite Analyzer (ICAN/PC)

Hygral, thermal, and mechanical responses can be analyzed for multilayered fiber composites.

The Integrated Composite Analyzer (ICAN/PC) is a computer program designed to carry out a comprehensive linear analysis of multilayered continuous-fiber polymer matrix composites. The analysis contains the essential features required for the effective design of structural components made from fiber composites. ICAN/PC includes the micromechanical design features of the Intraply Hybrid Composite Design (INHYD) program to predict hygral, thermal, and mechanical properties at the ply level. The laminate-analysis features of the Multilayered Filamentary Composite Analysis (MFCA) program are included to account for interply-layer effects. ICAN/PC integrates these and additional features to provide a comprehensive capability for analysis of composite structures.

Additional features unique to ICAN/PC include the following: (1) influence coefficients for stresses and strains in plies; (2) microstresses and microstrain influence coefficients; (3) stress concentration factors for material around a circular hole; (4) calculation of probable delamination locations around a circular hole; (5) details of Poisson's-ratio mismatch near a straight edge; (6) free-edge stresses; (7) material card input for finite-element analysis using NASTRAN (available separately from COSMIC) or MARC; (8) failure loads based on a maximum-stress criterion and laminate failure stresses based on first-ply failures and fiber-breakage criteria; (9) transverse shear, normal, and interlaminar stresses; and (10) durability/fatigue-type analyses for thermal as well as mechanical cyclic loads. The code can currently assess degradation due to mechanical and thermal cyclic loads with or without a defect. ICAN/PC includes a dedicated data bank of properties of constituent materials and enables the user to build a data base of properties of commonly used fiber and matrix materials so the user need only specify code names for constituents.

Input to ICAN/PC includes properties of constituent materials (or code names), factors that reflect the fabrication process, and geometry of the composite. ICAN/PC performs micromechanics, macromechanics, and laminate analyses, taking account of the hygrothermal responses of fiber composites. The output of ICAN/PC includes the various properties of plies and composite and results of stress analyses of composite, with details of failures. Output can be tailored to specific needs by choosing the appropriate options.

ICAN/PC is written in FORTRAN 77 for use on IBM or compatible personal computers running MS-DOS. The source code has been compiled by using Microsoft FORTRAN version 5.1. A sample executable code, along with sample

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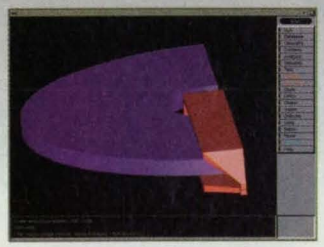

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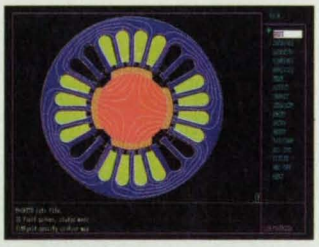

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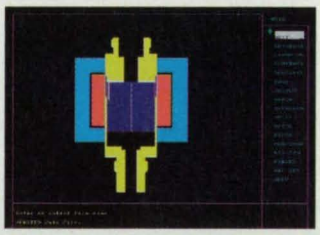

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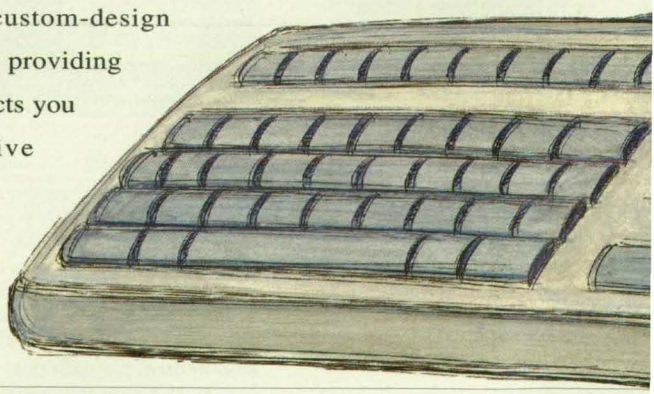

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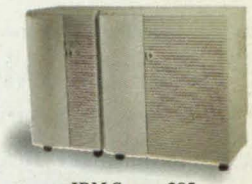

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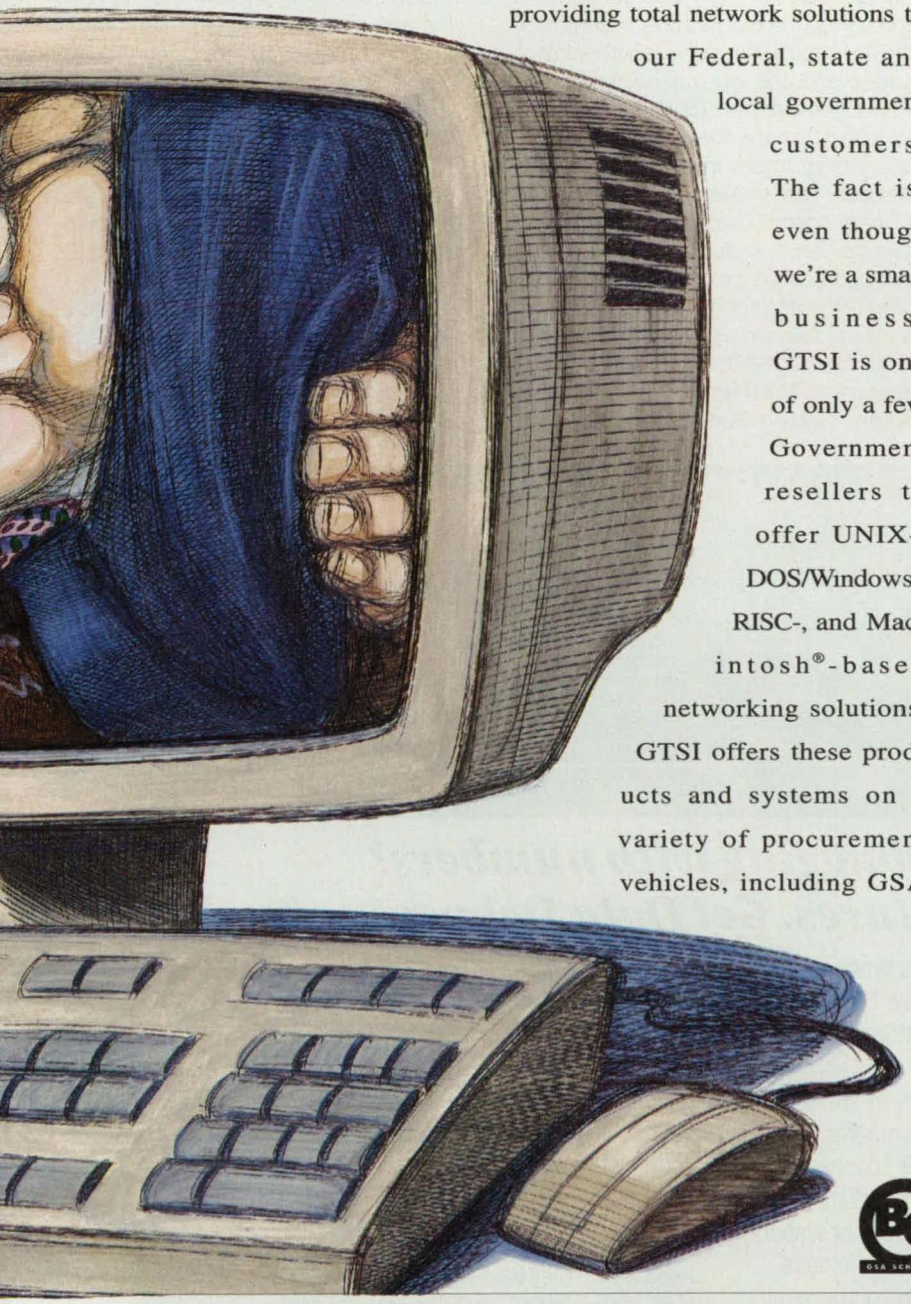

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input and output data, is included on the distribution medium. The use of a math coprocessor is highly recommended for 286 and 386 series personal computers; otherwise, the source code has to be recompiled by the user when a math coprocessor is not available. The distribution medium is one 5.25-in. (13.34-cm) 360K diskette in MS-DOS format. The contents of the diskette are compressed by use of the PKWARE archiving software tools. The utility program to unarchive the files, PKUNZIP.EXE, is included. Another machine version of ICAN for mainframe computers running under VM systems will be available soon.

This program was written by P. L. N. Murthy of **Lewis Research Center** *and S. K. Mital of University of Toledo. For further information,* ***write in 90*** *on the TSP Request Card. LEW-15592*

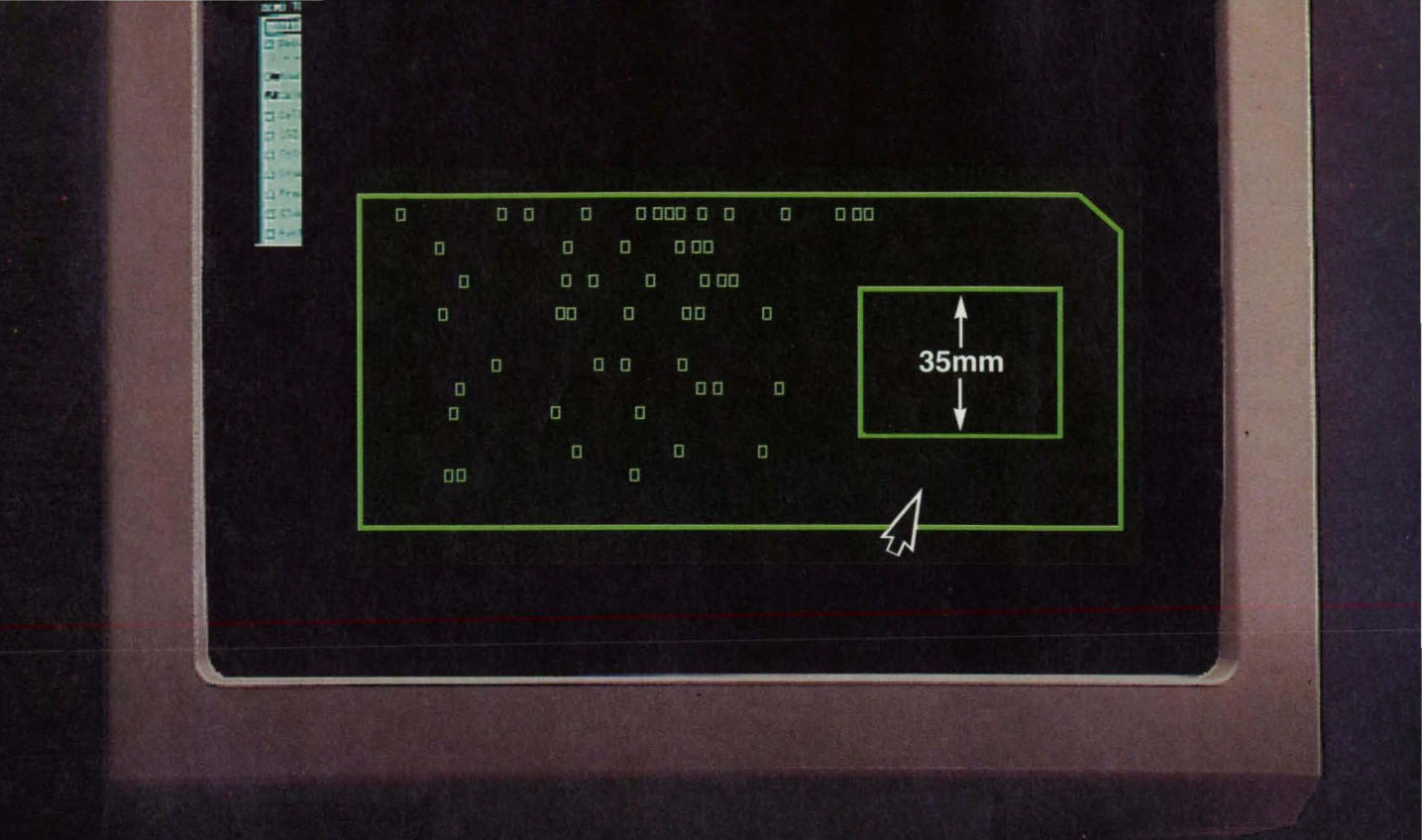
Program Aids Analysis and Optimization of Design

NETS/PROSSS provides forcombination of a neural-network application program with an optimization program.

Expensive analysis computer programs are often combined with optimization programs to solve engineering problems. Typically, an optimal solution requires numerous iterations between an analysis program and an optimization program. This often becomes prohibitive because of cost and the amount of computer time needed to converge to an optimal solution. The NETS/ PROSSS (NETS Coupled With Programming System for Structural Synthesis) computer program was developed to provide a system for combining NETS (MSC-21588), a neural-network application program developed at NASA's Johnson Space Center, and CONMIN (Constrained Function Minimization, ARC-10836), an optimization program developed at Ames Research Center. After training the neural network and saving the weights (the strengths of the connections between the input nodes and the output nodes in the neural network), NETS can be applied to approximate the results from an analysis program in the optimization process. This enables the user to reach a nearly optimal design. This design can then be used as starting point in a normal optimization process, possibly enabling the user to converge to an optimal solution in significantly fewer iterations.

NETS/PROSSS is written in C language and FORTRAN 77 for Sun computers running SunOS. The required CONMIN and NETS v3.0 files are included in this package. The documentation for CONMIN and NETS is included with the documentation of NETS/PROSSS. The program requires 342K of random-access memory for execution. The standard distribution medium for this program is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. It is also available on a 3.5-in. (8.89-cm) diskette in UNIX tar format. NETS/PROSSS was developed in 1991.

This program was written by James L. Rogers, Jr., of **Langley Research Center** *and William J. LaMarsh II of Unisys Corp. For further information,* ***write in 20*** *on the TSP Request Card. LAR-14818*



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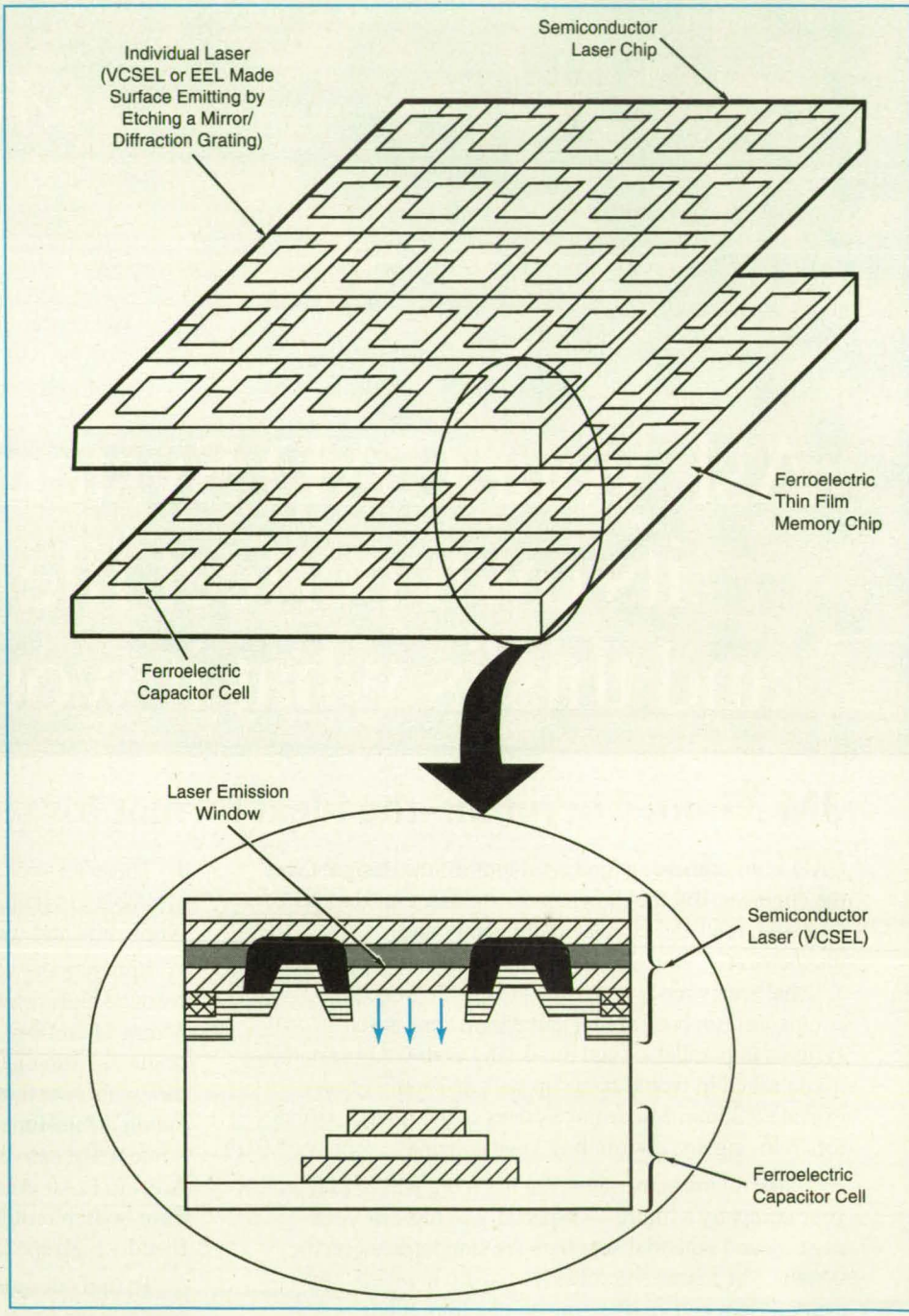
For readout, memory cells would be addressed via on-chip semiconductor lasers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed thin-film ferroelectric memory device would feature nonvolatile storage, optically addressable, nondestructive readout (NDRO) with fast access, and low vulnerability to damage by ionizing radiation. The contents of present ferroelectric memories are read out by sensing displacement currents during polarization switching, which destroys the contents. Polarization switching also fatigues the ferroelectric material; this effect limits the operating life to about 10^{10} recording/readout cycles. In the proposed memory device, polarization would still have to be switched during recording and erasure, but not during readout. As a result, readout would not destroy the contents of the memory, and the operating life in specific "read-intensive" applications could be increased up to an estimated 10^{16} cycles.

In principle, both electronic as well as thermal mechanisms could be triggered by photon exposure of ferroelectric thin films. The electronic photogenerated carrier effects may include photovoltaic/photoconductive effects, localized electronic transitions, and/or space charge transients. Thermally triggered mechanisms on the other hand would include pyroelectric effects (associated with temperature change of PZT) and/or piezoelectric effects (due to propagation through PZT of an acoustic deformation wave, initiated by sudden thermal expansion of the platinum top electrode in response to a short energetic photon pulse). Comparison of readout signals from devices with semitransparent and opaque top electrodes, respectively, suggests that the observed nondestructive readout (NDRO) signal component is primarily due to thermally triggered mechanisms. The readout process would therefore exploit these thermally triggered effects. The ferroelectric memory pixel would be illuminated with a high-speed (≤ 10 ns), intense-heating (≥10 μJ) laser pulse at a wavelength substantially less energetic than the bandgap (3.5 eV) of the ferroelectric memory film, to yield a polarization-direction-dependent photoresponse from the memory. Such readout has been observed to repeat over a million times, with no detectable degradation in the photoresponse or the remanent polarization,



This is a **Conceptual Design** of an optically addressable ferroelectric memory-chip pack.

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suggesting its potential as an NDRO of the nonvolatile polarization state in thin-film ferroelectric memories.

Shown in the figure is a conceptual architecture of an optically addressable ferroelectric memory in a dual-chip configuration where a semiconductor laser chip is flip-bonded onto the ferroelectric memory chip. Semiconductor laser arrays utilizing vertical-cavity surface-emitting laser (VCSEL) technology, or edge-emitting lasers (EEL's) with their output converted to surface emitting by etching a diffraction grating or a 45° mirror could be utilized for this purpose. Such semiconductor lasers delivering power in excess of a watt over an aperture of 5 mm x 5 μm at wavelengths of about 0.8 μm are now available. The architecture could be configured to allow readout of several bits (say 32 bits, one word at a time) using one such laser, thus keeping the wall-plug power requirement to less than a few watts, as would be desirable for a practical implementation.

This work was done by Sarita Thakoor of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 40*** *on the TSP Request Card.*
NPO-18573

Current-Collecting Grids for AMTEC Electrodes

Peak power was up to 50 percent greater than in equivalent electrodes without grids.

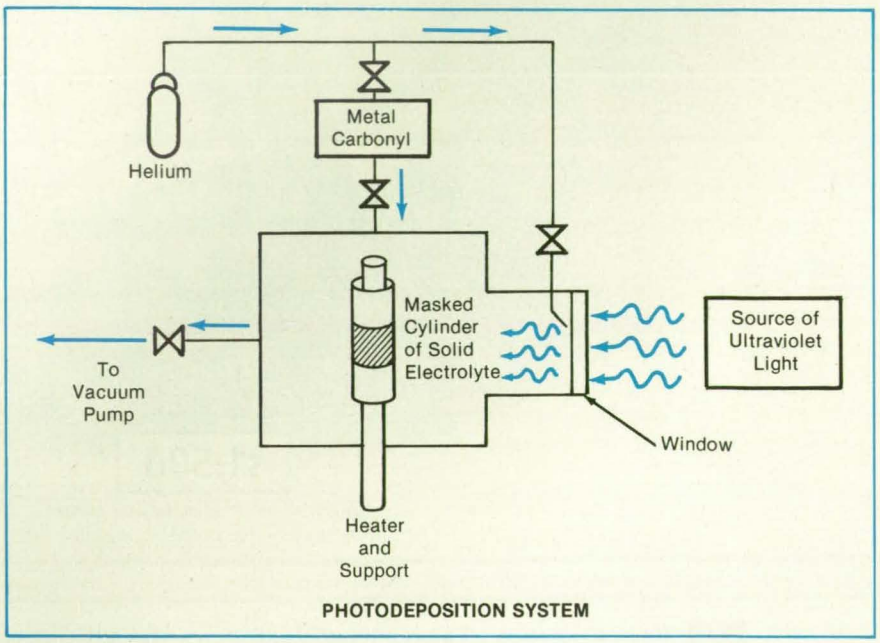
NASA's Jet Propulsion Laboratory, Pasadena, California

Photodeposition or sputter deposition of a refractory metal in a grid pattern on the solid electrolyte of an alkali-metal thermoelectric converter (AMTEC) prior to deposition of an electrode decreases the electronic resistance and increases the current and peak power of the converter significantly. This concept may also be applicable to other devices that include electrically conductive, porous electrodes; for example, solid-state fuel cells and solid-state electrolysis cells.

AMTEC's are capable of near-Carnot efficiencies. An AMTEC operated at the Jet Propulsion Laboratory includes a β″-alumina solid electrolyte ceramic tube, which separates a region that contains liquid sodium at a temperature of 900 to 1,300 K from a low-pressure region that contains a condenser at 400 to 700 K. The electrolyte is a conductor of sodium ions, which are produced by the oxidation of sodium metal at the interface between the liquid sodium and the solid electrolyte. The sodium ions travel through the solid electrolyte to the low-pressure side.

The electrons produced upon oxidation travel through an external circuit and recombine with the sodium ions at a porous, thin-film metal electrode that has been sputter-deposited onto the outside of the electrolyte tube. The sodium atoms then travel through the porous metal electrode, are desorbed as vapor on the low-pressure side, and condense as a liquid film on the condenser. The electrical resistance of the electrode, as measured in terms of sheet resistance and contact resistance, is high because the thickness of the electrode must be restricted to only 1 to 2 μm to maintain the porous character necessary to allow the passage of sodium.

An electrode can be thickened in selected regions (that is, a grid can be deposited) to decrease electrical resistance in those regions while maintaining porosity in the nonthickened regions. A grid for an AMTEC electrode can be photodeposited from organometallic vapor on a masked solid electrolyte as shown schematically in the figure, or alternatively, on a solid electrolyte on which the light is imaged in the desired pattern. A grid can also be deposited by sputtering a refractory metal like molybdenum or tungsten through a mask. An AMTEC electrode can then be deposited on the grid. Putting the grid under rather than over the electrode protects the grid against flaking or cracking during operation at a temperature ≥ 1,000 K.



Photolysis of a Metal Carbonyl can be used to deposit a grid of refractory metal on a solid electrolyte before depositing the outer electrode. The grid reduces electronic resistance while maintaining the porosity of the electrode.

Electrodes that include sputter-deposited underlying grids were tested in two configurations, each for more than 700 h. In all measures of performance (series resistance, exchange current, and peak power), electrodes with grids proved to be superior to those without. Mechanical tests of sputter-deposited grids showed them to be insufficiently adherent for long-term AMTEC operation, although subsequent treatments might be developed to improve their mechanical properties. Photodeposited grids were found to be more adherent and not easily lifted or scraped off the ceramic. Microscopic examination has shown photodeposited lines to be continuous and dense. Because of their greater adherence, photodeposited grids are expected to outperform sputter-deposited grids.

This work was done by Margaret A. Ryan, Roger M. Williams, Barbara Jeffries-Nakamura, Mark L. Underwood, Dennis O'Connor, and Stanley J. Kikkert of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 62*** *on the TSP Request Card.*
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Double-Square-Loop Triband Frequency-Selective Microwave Reflector

Double-square-loop antenna elements are arrayed on a dielectric panel.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates a dichroic microwave reflector that consists of a planar square array of double-square-loop copper elements on a thin sheet of Kapton (or equivalent) polyimide supported by a Kevlar (or equivalent) aromatic polyamid honeycomb sandwich panel. The array and panel are designed to reflect most of the incident electromagnetic radiation at frequencies between 7.2 and 8.4 GHz (in the X band) and to transmit most of that at 2.3 GHz (in the S band) and 13.8 GHz (in the K_u band).

The double-square-loop element is selected because its first resonant frequency is very stable with respect to the change of incident angle. The wavelength of this resont frequency is proportional to the circumference of the outer square loop for the case of a free-standing grid.

The initial dimensions and spacings for the design of this reflector were obtained by computing the effect of the dielectric support on the resonant (reflection) frequency, then modifying the prior dimensions accordingly so as to obtain the desired frequency-selective characteristics in the presence of the honeycomb panel. Measurements of performance and further computations showed the need to modify the dimensions further because the effective dielectric constant of the skin of the honeycomb panel was apparently lower than assumed in the initial computations (2.35 effective, 3.5 assumed). The

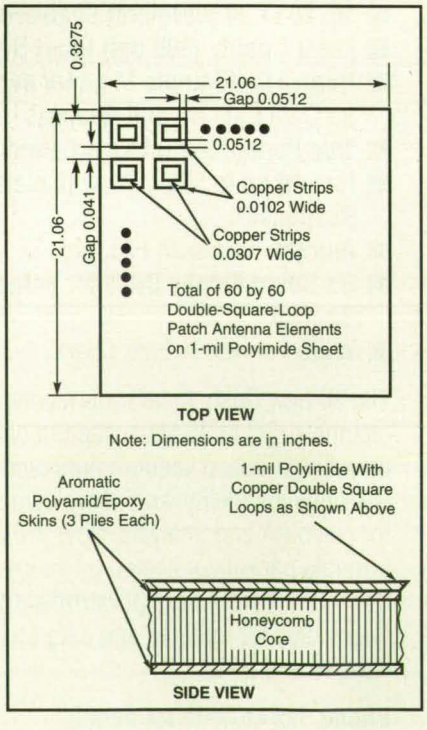

Figure 1. This Frequency-Selective Microwave Reflector is highly reflective at 8.4 GHz (X band) and highly transmissive at 2.3 GHz (S band) and 13.8 GHz (Ku band).

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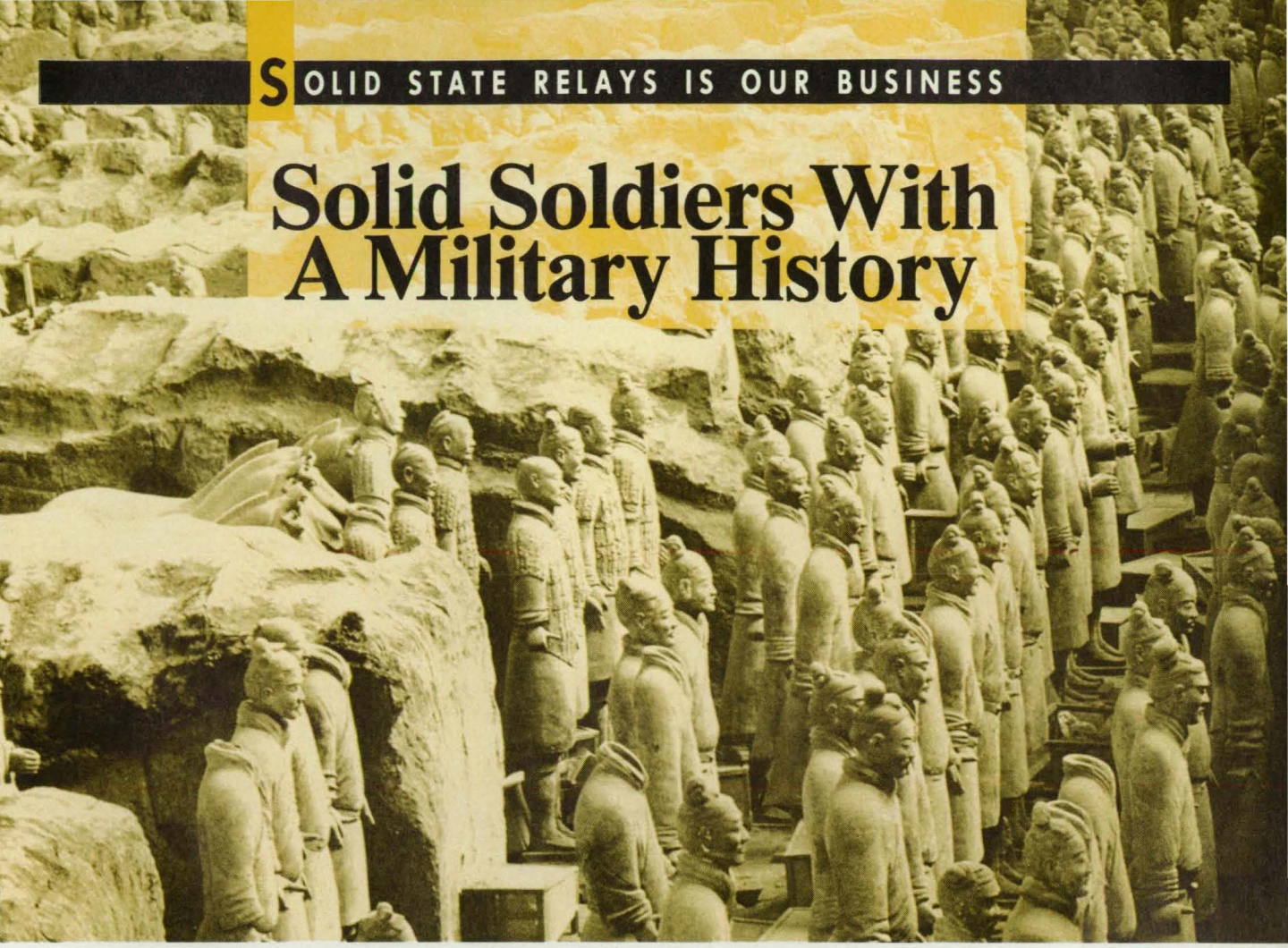

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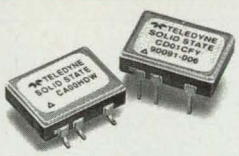

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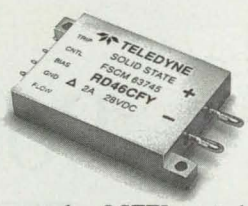

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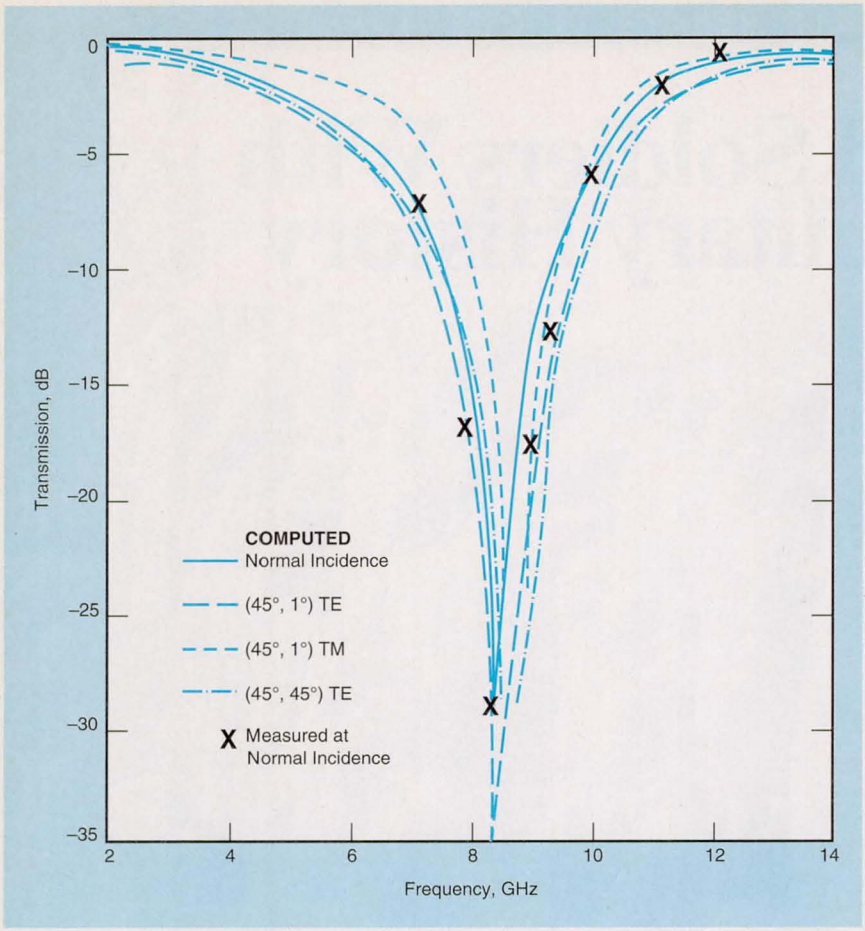


dimensions shown in the figure are those of this most recent design iteration. Figure 2 illustrates the computed transmission performance for several angles of incidence in transverse magnetic (TM) and transverse electric (TE) polarizations, as well as the measured performance at normal incidence.

This work was done by Te-Kao Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 88*** *on the TSP Request Card.*
NPO-18676

Figure 2. The **Measured Performance at Normal Incidence** agrees well with the computed performance at normal incidence. The computed performance at other angles of incidence is also shown to illustrate the wide angular range within which the desired frequency-selective characteristics can be obtained.

Triband Circular-Loop Frequency-Selective Microwave Reflector

Circular-loop antenna elements are embedded in a dielectric laminate.

NASA's Jet Propulsion Laboratory, Pasadena, California

Figure 1 illustrates a triband frequency-selective microwave reflector that consists of a planar square array of circular-loop conductive antenna elements sandwiched between dielectric sheets. The array reflects strongly at a frequency of about 8.4 GHz and transmits with little attenuation at frequencies of 2.3 and 13.8 GHz, at all angles of incidence within about 45° of normal.

This triband frequency-selective reflector is improved from the previous published design, "Triband FSS with Circular Ring Elements," *Int. IEEE AP-S Symposium Digest*, June 1991, pp. 204-207. Like the others, this dichroic reflector is designed for use in multiplexing signals at several frequencies in a microwave antenna system.

The outstanding feature of the present triband frequency-selective reflector is the simplicity of its design and fabrication. The previously reported design consists of two planar arrays of circular ring elements supported by non-space-qualified Duroid 6010.5 panels and separated by a foam spacer; the loop elements and arrays must be aligned with

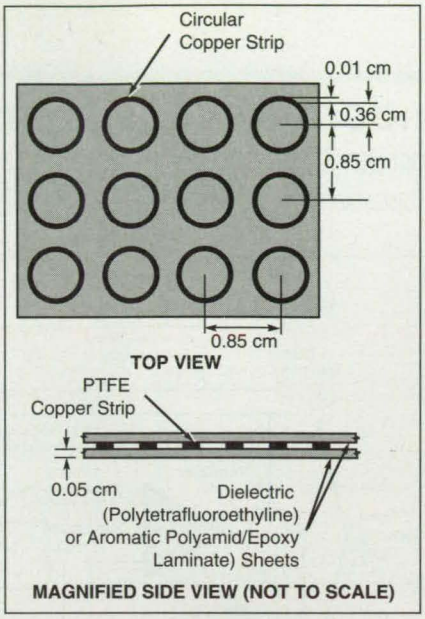


Figure 1. This **Dichroic Microwave Reflector** has the desired frequency-selective reflection/transmission characteristics over a range of angles of incidence, and can be fabricated rela-

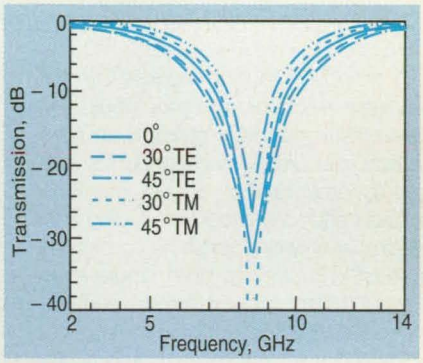


Figure 2. The **Transmission as a Function of Frequency** was calculated at normal incidence and in transverse magnetic (TM) and transverse electric (TE) polarizations at various other angles of incidence.

each other. The high dielectric constant (ε = 11) Duroid 6010.5 panels were required to avoid the forming of grating lobes at the Ku-band for the old design. However, the new design avoids the grating lobe by loading both sides of the grid array with lower dielectric constant (ε = 3.5) and space-qualified Kevlar/epoxy laminates. Figure 2 shows the computed performance of the present reflector in two polarizations, at various angles of incidence.

This work was done by Te-Kao Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 32*** *on the TSP Request Card.*
NPO-18714

Nonvolatile GaAs Random-Access Memory

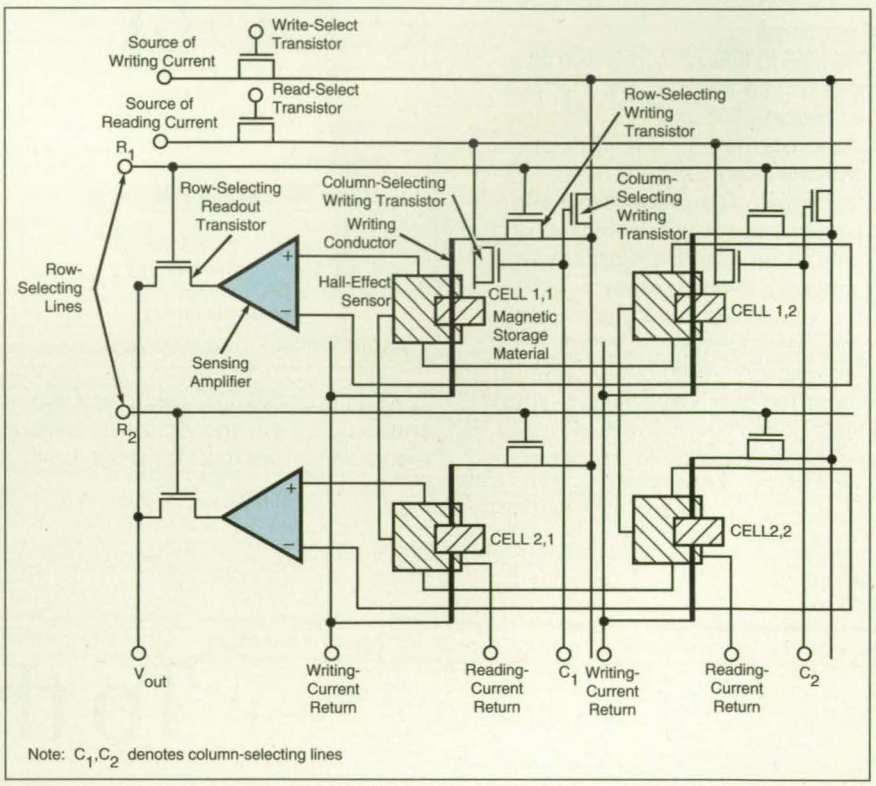
Bits would be stored magnetically and read out with Hall-effect sensors.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed random-access integrated-circuit electronic memory would offer nonvolatile magnetic storage. In comparison with present semiconductor static and dynamic random-access memories it would offer advantages, including short reading and writing times and a high degree of immunity to both single-event upsets (temporary bit errors) and permanent damage by ionizing radiation.

Each datum bit, represented by the state of magnetization of the magnetic storage material, would be sensed by a Hall-effect magnetic-field sensor operating in conjunction with an associated transistor and other readout circuitry. Both the magnetic-field sensors and the transistors would be made of high-charge-carrier-mobility and radiation-tolerant gallium arsenide. The high mobilities (in comparison with those in silicon-based devices) should result in writing and reading times ≤0.1 ns. The use of the same basic material for both transistors and sensors would simplify the fabrication process, with consequent benefits in increased yield and reduced cost.

The figure shows a four-cell version to illustrate the principal of operation. The write-select or read-select transistor would switch on the writing or reading current, respectively. During writing, the current from the writing source would be directed to a conductor that passes over the magnetic storage material in the selected memory cell, by turning on row- and column-selecting transistors for the row and column that intersect at that cell. The magnetic field generated by this current would magnetize the storage material, thereby recording a datum. During readout, reading current would be applied in series to all of the Hall-effect sensors in the column that contains the selected cell, while a row-selecting readout transistors would be turned on to pass the output of the sensing amplifier, to which all the Hall-effect sensors in the selected row would be connected in series.



Note: C_1,C_2 denotes column-selecting lines

The **Nonvolatile Memory** would contain magnetic storage elements and Hall-effect readout sensors. A practical version would consist of many more than the four cells shown here: versions as large as megabits on standard-size integrated-circuit chips are envisioned.

Preliminary calculations show that with extremely conservative design rules, one cell of the memory would occupy a square of 30 $\lambda \times 30\ \lambda$, where λ is the minimum circuit-feature size characteristic of the fabrication process. If λ = 1 μm, then such a design could fit a 64-kb memory onto an integrated-circuit chip of standard size. By reducing λ and optimizing the design, it should be possible to raise the capacity of a standard-size memory chip to 1 Mb or more.

This work was done by Romney R. Katti, Henry L. Stadler, and Jiin-Chuan Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 82*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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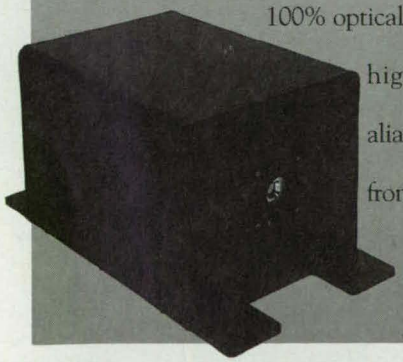

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For More Information Write In No. 538

Evaluating Multi-Input/Multi-Output Digital Control Systems

Controller-performance-evaluation methodology was validated on an aeroelastic wind-tunnel model.

Langley Research Center, Hampton, Virginia

Active controls are becoming an increasingly important means to enhance the performances of aircraft. Because the process of designing multi-input/multi-output (MIMO) digital control laws involves the use of relatively untested theoretical methods, it is necessary to validate the design methodology through experimentation. Accordingly, a controller-performance-evaluation (CPE) methodology for MIMO digital control systems was developed. The CPE procedures identify potentially destabilizing controllers and confirm the satisfactory performance of stabilizing ones.

A simplified block diagram of the basic closed-loop control problem is shown in the top part of Figure 1. The plant to be controlled is represented mathematically by a frequency-domain transfer matrix, **G**, with outputs **y** and inputs **e**. The controller is represented mathematically by a transfer matrix, **H**, with inputs **y** and outputs **x**. External excitation **u** is used to excite the system in a specified fashion. This excitation is used to derive transfer functions between outputs and inputs in either open- or closed-loop versions of the system. In the open-loop version of the system, the control-law outputs are not fed back into the system; i.e., the switch depicted in the lower part of Figure 1 is open.

The CPE computations involve the generation of frequency-domain transfer functions of plant outputs, **y**, and control-law commands, **x**, that are generated in response to an excitation, **u**. Fast-Fourier-transform (FFT) techniques can be used to calculate these functions. The controller, H, and the return-difference matrices, $I + GH$ and $I + HG$, and their singular values are then calculated by use of matrix operations. Figure 2 outlines the CPE procedures.

This methodology was used and validated during the wind-tunnel testing of an aeroelastic model equipped with a digital flutter-suppression controller. The methodology is generic and can be used in many types of multi-loop digital-controller applications, including digital flight-control systems, digitally controlled spacecraft structures, and actively controlled wind-tunnel models. It may also be applicable to other complex, highly dynamic digital controllers, such as those in high-performance robot systems.

This work was done by Anthony S. Pototzky of Lockheed Engineering & Sciences Co. and Carol D. Wieseman, Sherwood T. Hoadley, and Vivek Mukhopadhyay of **Langley Research Center**. *For further information,* ***write in 91*** *on the TSP Request Card.*
LAR-14635

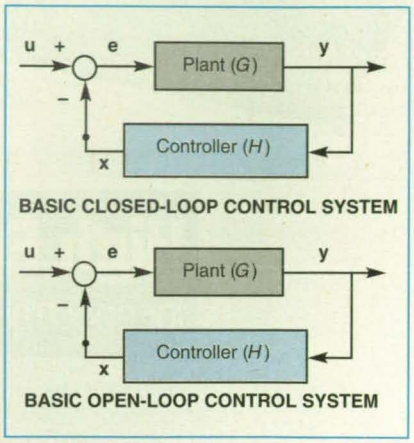

Figure 1. **Both Open- and Closed-Loop Systems** are accommodated in the CPE methodology.

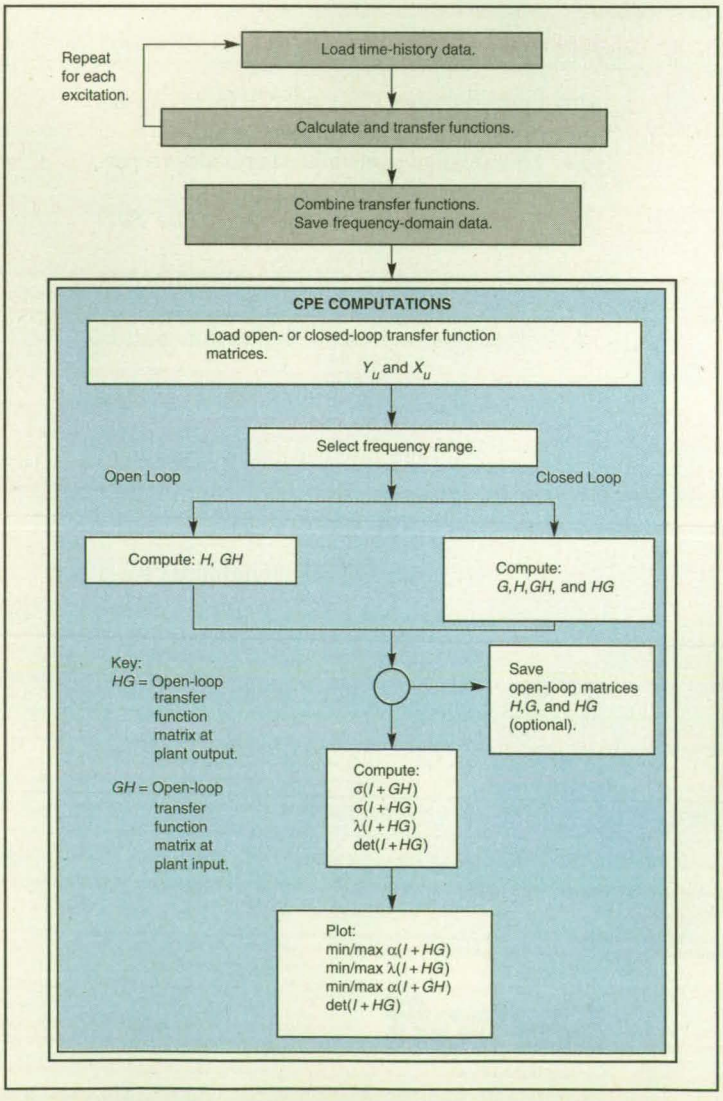

Figure 2. This **Flow Chart** illustrates the application of the CPE methodology to a multivariable digital control system.

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Langley Research Center, Hampton, Virginia

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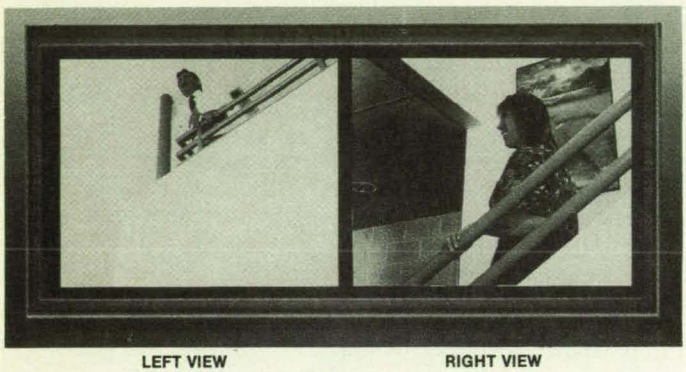

LEFT VIEW RIGHT VIEW

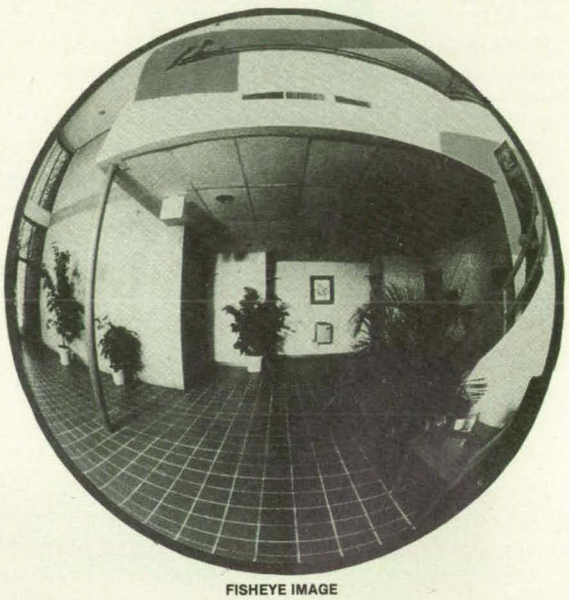

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Figure 1. The **Full Hemispherical Fisheye Image**, with barrel distortion, is separated into smaller, distortion-free images. Two images can be displayed simultaneously, side by side.

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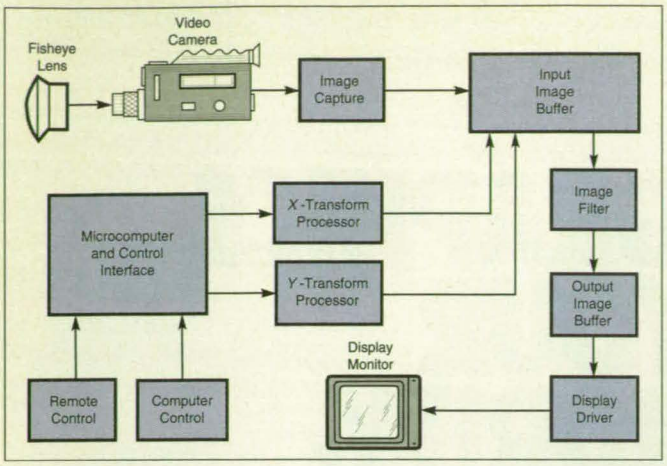


Figure 2. The **Microcontroller Does Preliminary Calculations** for transform processors in addition to providing an interface for remote control and computer control signals. The transform processors correct distortion and orient the selected portion of the image as if the camera pointed straight toward it, regardless of the position of that portion in the view of the fisheye lens.

of view or to break an image into sectors for simultaneous viewing, thereby replacing several cameras.

The camera includes a fisheye lens, which creates a circular image of a hemispherical field of view (see Figure 1) on a charge-coupled device (CCD). The image data are stored briefly in an input image buffer for processing (see Figure 2). High-speed *x*- and *y*-transform digital processors correct the barrel distortion introduced by the fisheye lens and thereby enable the reconstruction of undistorted views of portions of the scene, as directed by a microprocessor. A human operator programs the microprocessor through a control panel, choosing the magnification, viewing direction, and offset of the selected portion of the image.

The associated electronic circuitry includes a 32-bit microprocessor with 80-bit floating-point arithmetic support for parametric calculations. It performs control interface functions and calculates the coefficients for the *x*- and *y*-transform processors, which are independent arithmetic devices. The prototype system produces as many as 22 frames per second. An improved version is expected to produce 30 frames per second.

This work was done by Steven D. Zimmermann of TeleRobotics International, Inc., for **Langley Research Center**. *No further information is available.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Dr. H. Lee Martin, President
TeleRobotics International, Inc.
7325 Oak Ridge Highway,
Suite 104
Knoxville, TN 37931

Refer to LAR-14764, volume and number of this NASA Tech Briefs issue, and the page number.

Optical Pattern Recognition With Self-Amplification

The intensity of the recognition signal is orders of magnitude greater than in other optical correlators.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental optical pattern-recognizing apparatus features self-amplification of the output light beam in a photorefractive crystal. As in other optical correlators, the intensity of the output light beam is a measure of the correlation between an input image (which one seeks to recognize) and a prerecorded reference image. In this apparatus, the intensity of the pattern recognition signal is about 10^5 times as strong as in other optical correlators that lack the self-amplification feature.

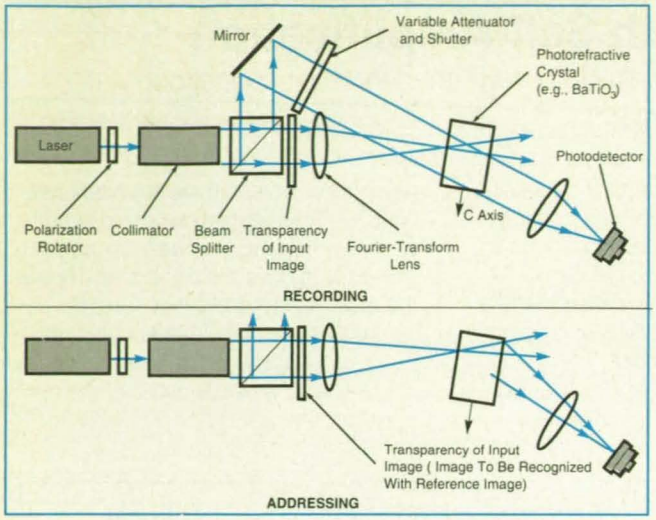
This apparatus can be regarded as a real-time or quasi-real-time optical pattern recognizer with memory and reprogrammability. The reference image is recorded immediately prior to addressing (readout). During recording, a polarized, collimated laser beam is split into an object and a reference beam. The object beam passes through a transparency of the reference image and is then focused by a Fourier-transform lens onto the facing surface of the photorefractive crystal. The reference beam is directed toward the photorefractive crystal at an angle with the object beam. The two beams interfere in the crystal, forming a volume hologram via the photorefractive effect.

During addressing, the reference beam is blocked, and the transparency of the reference image is replaced by a transparency of the input image that one seeks to recognize using the reference image. The output beam is produced by diffraction of the object beam (which now bears the input image) in the volume hologram. The output beam travels along the path of the reference beam that was used in recording the reference image. A lens that has been aligned previously with the reference beam focuses the output beam onto a photodetector, the electrical output of which is taken as the pattern recognition signal.

As used here "self-amplification" denotes a complex of effects that result from the particular optical configuration and the photorefractive effect. Among other things, it involves coupling between the reference or diffracted plane wave and the spherical wave produced by the Fourier-transform lens. One of the benefits of this self-amplification is that the pattern recognition signal contains less noise than does a correlation signal in a conventional optical correlator that is electronically post-amplified to the same level.

The same photorefractive effect that is exploited to record the image also causes the image to fade during addressing. The rate of fading increases with the intensity of the addressing beam; characteristic times for fading range from seconds to minutes, depending on the level of illumination. This effect can be exploited to erase the reference image, possibly in preparation for recording a new one.

In the self-amplified optical pattern-recognition system, three important functions — i.e., recognition, noise filtering, and amplification — can be accomplished all at once in a tiny crystal. Though the architecture and procedure are very similar to those of the well-known Vander Lugt matched-filter correlator because of the unique characteristics of the non-



In the **Optical Pattern Recognition System With Self-Amplification,** no reference beam is used in addressing mode. The polarization of the laser beam and the orientation of the photorefractive crystal (as indicated with reference to its *c* axis) are chosen to maximize the photorefractive effect.

linear photorefractive material, the results and applications are quite different. For example, extremely weak signals in a cluttered background can be recognized in the new system.

This work was done by Dr. Hua-Kuang Liu of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 76*** *on the TSP Request Card.*
NPO-18648

Computer-Aided Remote Driving

Stereoscopic still video images are used to designate paths.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system for remote control of a robotic land vehicle requires only a small radio-communication bandwidth — only a fraction of the many-megahertz bandwidth that is necessary for direct teleoperation.

In direct teleoperation, the vehicle would transmit video images of the terrain as it traversed a path, while a human operator at a remote control station would send detailed steering and speed commands to guide the vehicle around or over obstacles. Communication would have to be nearly instantaneous; transmission delay should be no more than milliseconds.

However, in this system, the vehicle

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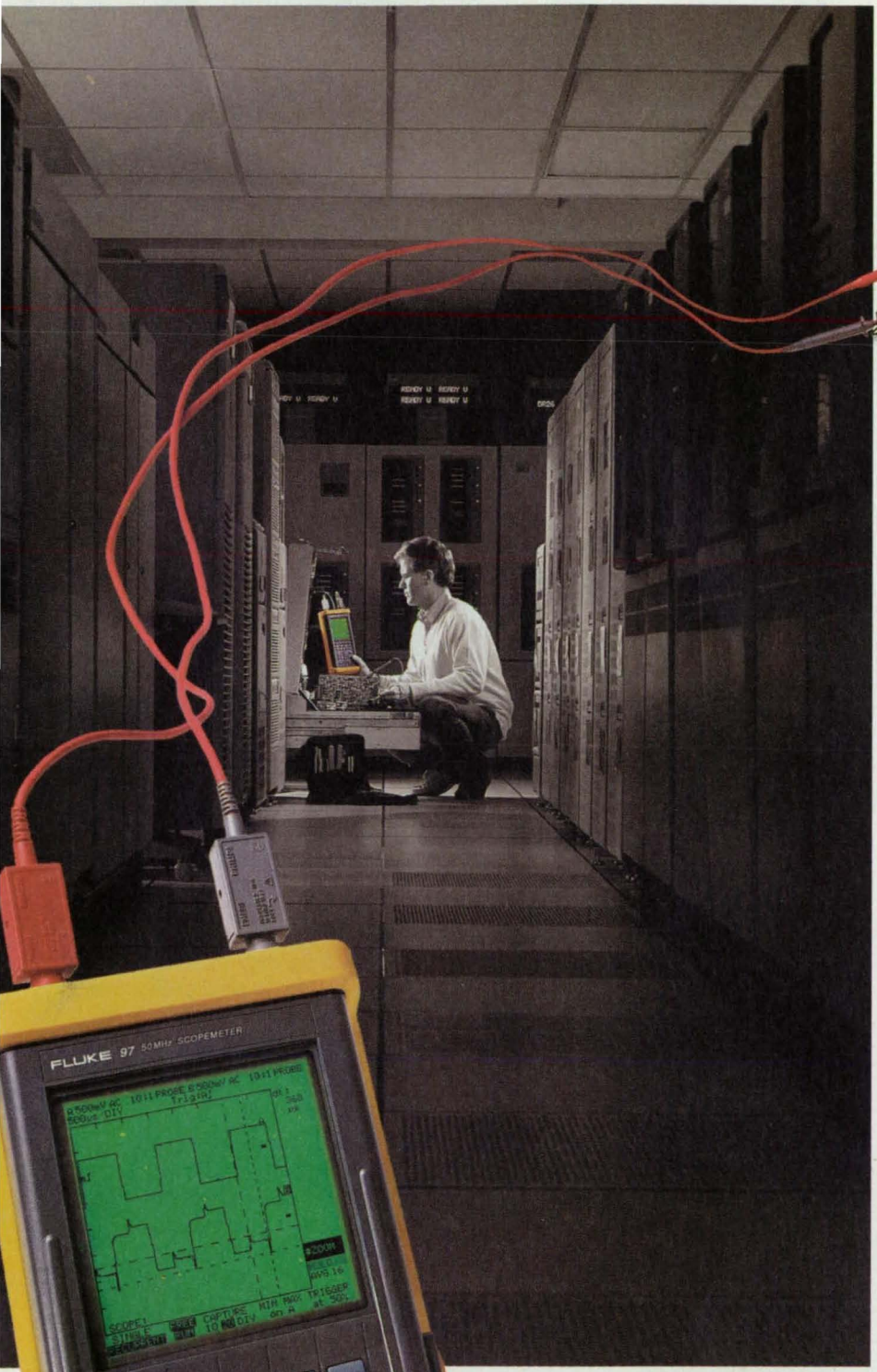
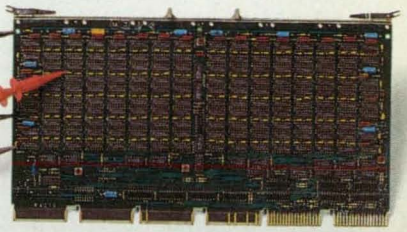


The **ScopeMeter** test tool is a handheld oscilloscope, digital multimeter and frequency counter. And its compact size is great for troubleshooting electronics, computer hard drives and power supplies.



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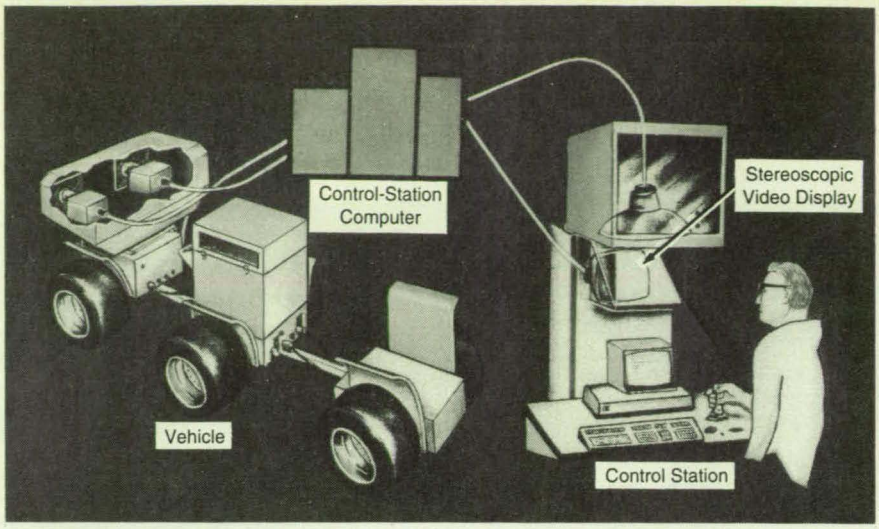

Twin Video Cameras on the vehicle create stereoscopic images. The operator views cross-polarized images on two cathode-ray tubes through correspondingly polarized spectacles.

sends only an occasional pair of images — a stereoscopic snapshot of the terrain — as it prepares to set out on a path. By use of a cursor on the frozen image, the remote operator designates a path. The vehicle proceeds to follow the path, by use of a limited degree of autonomous control to cope with unexpected conditions (e.g., small obstacles). In this system, the vehicle can be controlled not only with a small communication bandwidth but also under conditions of intermittent availability of the communication channel and significant transmission delay. The system concept, called "computer-aided remote driving" (CARD), is potentially useful where such conditions prevail: exploration of other planets, military surveillance, firefighting, and cleanup of hazardous materials, for example.

The snapshot of the terrain is displayed stereoscopically to the operator; that is, the operator's left and right eyes see images from the left and right cameras, respectively, of the vehicle (see figure). Stereoscopic imaging is essential to the CARD concept in that it takes advantage of (1) the human operator's ability to perceive depth and other aspects of the relative geometry of the terrain and the vehicle and (2) the ability of the control computer to extract the position of the cursor and the coordinates of the designated path in the coordinate frame of the vehicle.

The operator uses a hand controller (joystick, trackball, or spaceball, for example) to maneuver the cursor in the stereoscopic images. With the cursor, the operator designates a sequence of acceptable vehicle positions, which are interconnected into a planned path by an algorithm that takes into account the kinematic limitations of the vehicle; for example, its minimum turning radius.

The planned path is encoded and transmitted to the vehicle along with additional information the operator may want to supply; for example, the desired speed and expected pitch and roll values. The computer aboard the vehicle expands the coded information into continuous speed and steering commands as the vehicle travels the designated path. If an unforeseen obstacle appears, the vehicle circumvents it if possible; otherwise, it stops.

A key feature of the CARD system is that it does not need an expensive and accurate inertial navigation subsystem. It suffices to equip the vehicle with an odometer and with a flux-gate magnetic compass, which serves as heading-reference unit that is stable over a single cycle of planning and traversal of a path. The computed position and orientation of the vehicle with respect to the terrain data base can be recalibrated by occasional sightings of landmarks.

The CARD concept has been demonstrated in a test vehicle over a course about 40 meters long. With further improvements, distances up to 200 meters could be traversed before the vehicle would need a new planned trajectory designated by the operator.

Of course, a fully autonomous vehicle would offer a better solution to problems of remote control, but technology is not yet equal to that challenge. In the meantime, the CARD concept promises to meet the need for control with limited bandwidth.

This work was done by Brian H. Wilcox of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 101*** *on the TSP Request Card.*
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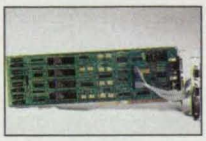

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Omega's new OMG-ISO-COMM boards have two or four isolated RS-422/485/232 ports with extended AT interrupts for DOS and Windows software. Based on the 16550 UART, these boards provide two or four serial ports each with 500 V of electrical isolation. Isolation is important where equipment connected to the PC is far from the PC or on a different power transformer circuit. For more information, request OMEGAfax℠ Document #6292 by calling 1-800-848-4271.

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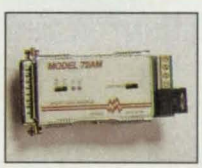

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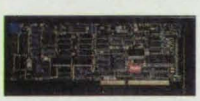

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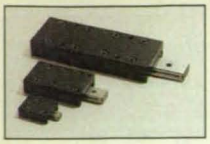

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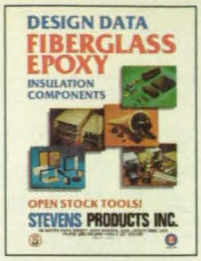

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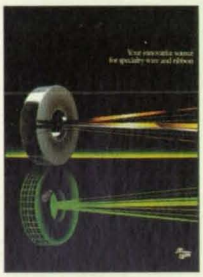

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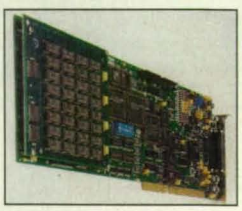

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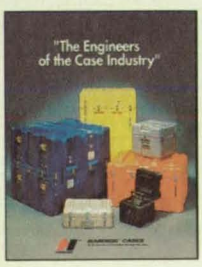

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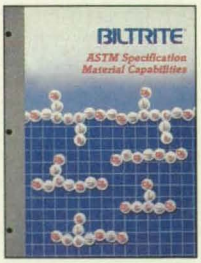

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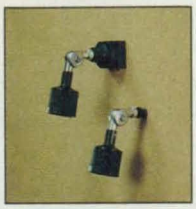

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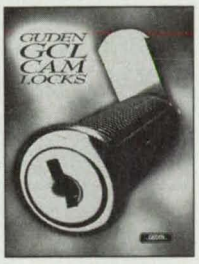

GCL CAM AND DRAW LOCKS

New catalog presents Guden's complete line of GCL Cam and Drawer Locks to complement their hinge, latch, clasp, handle, lid support and gas spring products. Full variety of stock items plus customized locks. Personal service and instant shipments on even the smallest orders. Easy-Order part number system. Ask for the GCL Catalog. H.A. Guden Co., Inc., 99 Raynor Ave., Ronkonkoma, NY 11779. Tel: 1-800-344-6437 or 516-737-2900; Fax: 516-737-2933.

H.A. Guden Co., Inc.

For More Information Write In No. 325

ESTIMATING WITH CAD

The COSTIMATOR® system now allows cost estimating of new products using most CAD systems. Estimates are reported to be within 5% of actual costs with this new mouse-driven system. DFM compatible. Easy to use. Fast payback.

Manufacturers Technologies, Inc.
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For More Information Write In No. 326

TIG TORCH SELECTOR

Versa-Tig™ Systems allow multiple torches to share one power source. Use with any tig torch & power source. Perfect when a variety of materials, thicknesses, joint geometries and combinations of welds or setups require multiple torch options. Uses: manual & fixtured torches, wire-feed Tig torches, seam/lathe-welders, turntables, welding chambers & orbital tube welders. Systems allow operators to "dial in" the desired torch or setup in "2 seconds" without tools!

Stainless Design, Inc.,

For More Information Write In No. 327

NEW MOTION CONTROL PRODUCT GUIDE

Aerotech's new 248-page Motion Control Product Guide provides in-depth technical data and design information for our linear and rotary positioning stages; microstepping motors and translators, servo motors and drivers (both DC and brushless); position transducers; and motion controllers (from one to 16 axes). Aerotech, Inc. 101 Zeta Drive, Pittsburgh, PA 15328. Tel: 412-963-7470; Fax: 412-963-7459.

Aerotech

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LOW-COST DIGITAL VIBRATION CONTROLLERS

Easy to use VTS Expansion Card & Software convert your 386/486 personal computer to powerful Digital Sine or Random Vibration Controller. Frequency ranges—Random 500, 1000, or 2000 Hz. Sine to 6250 Hz. Many other unique features. Free Demo Disk available (learn to operate Controller in less than one hour). Coming Soon—Accelerometer Calibrator & Shock Controller.

Vibration Test Systems

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StressTel Corporation

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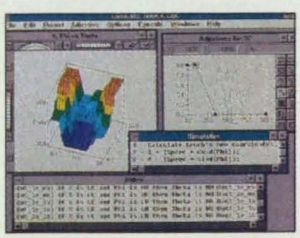

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Apply fuzzy logic interactively with CubiCalc's built-in simulation language, plots, file I/O and other features. Or use CubiCard's integrated data acquisition board and drive external hardware directly.

HyperLogic Corporation
Tel: 619-746-2765; Fax: 619-746-4089.

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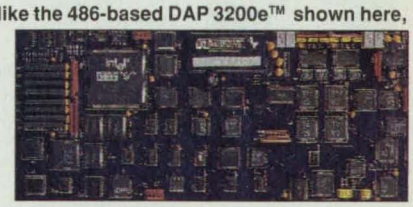
The Intelligent Solution for Data Acquisition

A Data Acquisition Processor™ board, like the 486-based DAP 3200e™ shown here, has its own on-board multitasking real-time operating system, DAPL™, that does the time-critical work in an application.



DAPwindows™, running on the PC under Windows, can issue commands to DAPL to acquire data or control processes in real time through the Data Acquisition Processor.

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MICROSTAR LABORATORIES™

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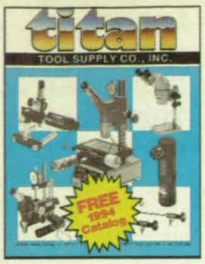
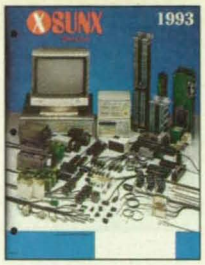


OPTICS FOR METROLOGY

New 1994 Catalog contains 120 pages of information and prices on toolmaker's microscopes, stereo microscopes, alignment microscopes, monocular zoom microscopes, microtelescopes, pocket microscopes, borescopes, micro video lenses, and fiber optic and miniature illumination systems. Also described are centering microscopes, optical cutting tool geometry analyzers, X-Y tables, and micro-finishing equipment.

Titan Tool Supply Co., Inc.
Tel: 716-873-9907; Fax: 716-873-9993.
For More Information Write In No. 334



SUNX SENSORS

NEW 34 page brochure featuring photo-electric, fiber optic, proximity, miniature, micro-photo, pressure/vacuum, area, linear array, color discrimination, analog output, and ultrasonic sensors. Also, rotary shaft encoders, optical identification systems, ultraviolet beam sensors, light curtain-area sensors, laser beam and wafer address sensors. 1207 Maple Street, West Des Moines, IA 50265. Tel: 1-800-280-6933; Fax: 515-225-0063.

SUNX Sensors/ Ramco Electric Co.
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Fax: 203-261-8331.
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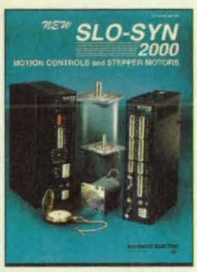

STEPPER MOTOR CONTROLS

Catalog SS2 792 describes new SLO-SYN® 2000 Motion Controls. Bipolar chopper drive has switch-selectable current settings from 1 to 6 A, 10 switchable motor microstepping resolutions from 200 to 50,000 pulses/rev. Programmable motion control permits 2 axes of control (non-simultaneous) for price of one, 16 inputs and 8 outputs fully protected. Call 1-800-447-7171.

Superior Electric
1994 Design Show Booth # 2657
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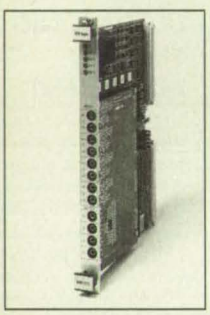

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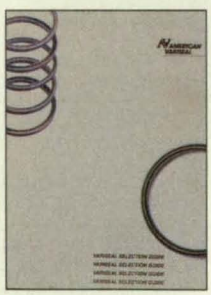

NEW SEAL SELECTION GUIDE

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American Variseal
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Tadco
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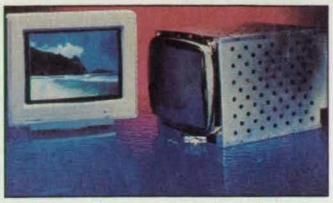

Modgraph, Inc. offers custom configured monitors ranging in size from 8.5" to 29." Touch Screens, 12/24/48 Volt DC power, industrial enclosures, open frame models and rackmounts are available for most display sizes. ***Modgraph*** can be reached at 1-800-327-9962. ***Modgraph, Inc.***, 6 Gill Street, Woburn, MA 01801. Tel: 617-938-4488; Fax: 617-938-4455.

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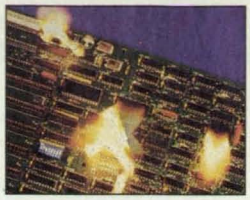

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CATALOG OF ENGINEERING FINDINGS

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Tel: 800-444-6223; Fax: 317-469-4130.

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Servometer Corporation

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Firestone Industrial Products
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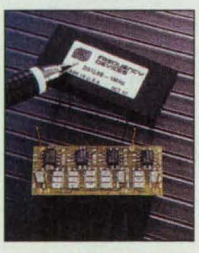

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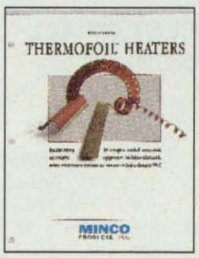

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Minco Products, Inc.

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Design, Analysis and Research Corporation

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AMCO Engineering Company

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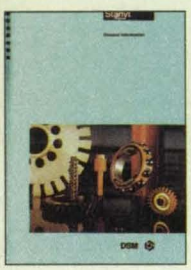

Stanyl 46 nylon offers outstanding property characteristics in demanding automotive, electrical/electronic and mechanical applications. This high-heat material offers cost-effective solutions with faster molding cycles. For a 20-page brochure, please contact DSM Engineering Plastics, Stanyl Marketing Center, 501 Crescent Avenue, Reading, PA 19612. Tel: 800-366-6923.

DSM Engineering Plastics

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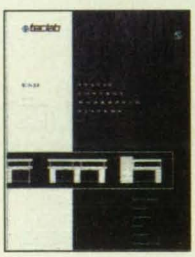

TECLAB ESD WORKSTATION CATALOG

Kalamazoo Technical Furniture's 8-page 4/color brochure details the Teclab line of static protective workbenches, workstation systems, and ESD controlled workstation accessories. Included are color options, product specifications, and various levels of ESD protection available. Teclab also offers a Free Planning and Design Service. Teclab, the "professional's bench." Tel: 1-800-832-5227. Fax: 616-372-6116.

Kalamazoo Technical Furniture

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International Designs Ltd.

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SAGA CAD & Drafting Supply

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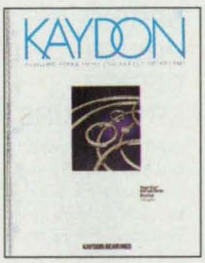

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Kaydon Corporation

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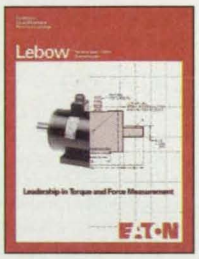

Eaton Corporation, Lebow Products is an industry leader in the manufacture of high quality, high precision, rotary inline and reaction torque sensors as well as fatigue resistant and general purpose load cells. We have over 35 years experience in torque and force measurement. Tel: 1-800-338-8099, ext. 2040; Fax: 810-642-0259.

Eaton Corp., Lebow Products

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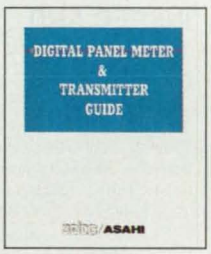

DIGITAL PANEL METER & TRANSMITTER GUIDE

New 8-page product guide summarizes Selco/Asahi's digital instrument line: DC and AC voltmeters and ammeters, process monitors, setpoint comparators, counters, tachometers, frequency meters, strain gauge meters, thermometers, remote monitors, transmitters, modular DPM and DC power supplies. Over 80 models with information on size, number of digits, and measurement setups. Tel: 714-521-8673, 800-229-2332; Fax: 714-739-1507.

Selco/Asahi

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Today's demanding manufacturing environment requires test solutions that rapidly adapt to changing products. Low cost, high flexibility, long service life and a minimum of special skills requirements set the FTMS™ VXI/GPIB test system apart from all other test solutions. It's the easiest ATE operating environment you'll ever use. Westinghouse-Flexible Test & Measurement Systems Group, 18901 Euclid Ave., Cleveland, OH 44117. Tel: 216-692-5179.

Westinghouse-Flexible Test & Measurement Systems Group

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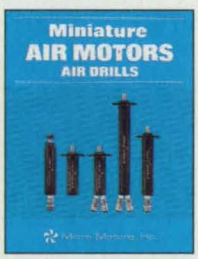

MINIATURE AIR MOTORS

Brochure lists size and performance options to help you select the smallest, most efficient Air Motor to meet your needs. Stainless, rotary vane designs produce stall torques from 3.5 in-ozs to 9 ft-lbs and free speeds of 50,000 RPM to 1 RPM.

Micro Motors Inc.

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HEIDENHAIN'S 52 page General Catalog features mechanical and technical information on Linear and Rotary Encoders, Digital Readouts, Numerical Controls and Digital Height Gages for measurement and inspection applications. Metal-cutting and metal-forming machines, inspection equipment, general automation and the electronics industry are just a few of the various types of applications that require measurement systems for position and speed control feedback.

Heidenhain Corporation

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Brochure shows configurations of custom-built inflatable rubber seals. When inflated, a positive seal is formed between two surfaces. It's the solution for sealing out weather, water, noise, heat, cold, light, dark, pressure, vacuum, radiation, dust and contaminants. Design assistance available. Tel: 216-673-8410; Fax: 216-673-8242.

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SHAFT HUB LOCKING DEVICES

32 page catalog details our line of keyless, frictional locking devices for securing any rotating component to shafts from 1/4"—40". Catalog contains technical data & dimensions, selection guides and application information. Westwood, NJ office—Tel: 800-245-2580; Fax: 201-664-6053. Los Angeles office—Tel: 714-581-3644; Fax: 714-581-5956.

Ring Feder Corp.

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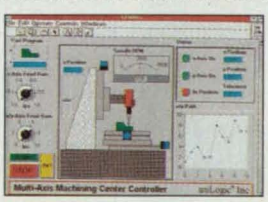
WINDOWS MOTION CONTROL SOFTWARE



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Design Engineering Product Showcase

COMPLETE MOTION CONTROL SOLUTIONS

High Performance Servo & Stepper Controllers for PC/AT ISA Bus and Macintosh computers. 1-4 axes of control with Power Amplifier and Interface Units. Easy-to-use software including pcRunner Windows *Double-Click* application, DLLs, LabVIEW Motion VIs, Visual Basic, QuickBasic and C drivers.

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- ACOUSTIC INTENSITY
- REALTIME 1/3 OCTAVE ANALYSIS
- SHOCK RESPONSE SPECTRUM

DATA PHYSICS CORPORATION
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Tel: 408-977-0800; Fax: 408-977-0801
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DIGITAL SHAKER CONTROLLER

DP540 Vibration Controllers use DSP boards in your PC for high performance at low cost.

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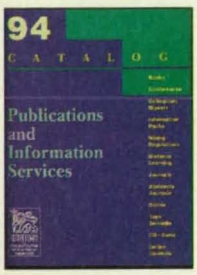

INSPEC AND THE IEE COMBINE CATALOG

INSPEC Publications and Services, Abstracts Journals, Online Database, Tape Services, CD-ROM, IEEE/IEE Periodicals Ondisc (IPO) are featured along with the Books, Conference Proceedings, Professional Journals and Distance Learning (Video and CBT) materials of the Institution of Electrical Engineers (IEE). Tel: 908-562-5553; Fax: 908-981-0027.

IEE/INSPEC
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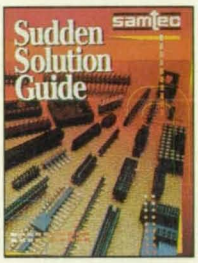

FULL LINE SAMTEC CATALOG

Samtec's new Full Line Catalog F-193 includes complete ordering information and specifications on many new interconnects. Micro, surface, board-to-board, IDC cable assemblies and custom design capabilities are shown. A new sixteen page full color interconnect applications section is included. Samtec, Inc. P.O. Box 1147, New Albany, IN 47151-1147. Tel: 800-SAMTEC-9 (800-726-8329) Fax: 812-948-5047.

Samtec, Inc.
For More Information Write In No. 385

SPRING POWER DESIGN LITERATURE

Ametek Hunter Spring Bulletin FS-201 provides complete descriptive and technical data for broad line of stock and custom spring powered devices. Product information covers SPIR'ATOR prestressed spiral springs, NEG'ATOR constant force extension springs and spring motors, as well as other power spring packages and stock mechanical reels. Tel: 215-257-6531; Fax: 215-257-4711.

AMETEK U.S. Gauge Division
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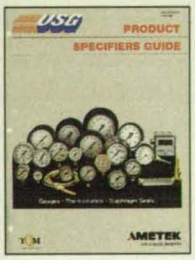

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AMETEK U.S. Gauge Division offers a complete line of process gauges for the CPI...critically accurate test gauges for lab calibration...liquid filled gauges for corrosion and vibration resistance...LVDT pressure transducers...and digital electronic temperature instrumentation. U.S. Gauge is a global TQM manufacturer with products supported by a worldwide network of stocking distributors. AMETEK U.S. Gauge Division, Sellersville, PA 18960. Tel: 215-257-6531; Fax: 215-257-4711.

AMETEK U.S. Gauge Division
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BRUSHLESS DC MOTORS

This new, standard line is developed around 2.0" and 3.2" diameter lamination sizes. Motors are available in different stack lengths to meet a wide performance range. This line features minimal tooling, Hall Effect switches, and a variety of motor lengths and torque ranges. The eight-pole/12-slot motors accept 12-40 VDC imput power. Applications include medical devices, business machines, and computer peripherals. AMETEK Technical Motor Division, 627 Lake Street, Kent, OH 44240. Tel: 216-673-3452; Fax: 216-678-8227.

AMETEK Technical Motor Division
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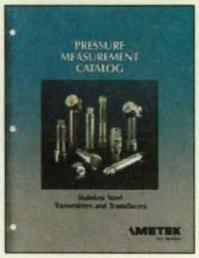

STAINLESS STEEL TRANSMITTERS AND TRANSDUCERS

AMETEK PMT Products Group offers a full line of transmitters and transducers to provide pressure measurement solutions to a variety of industries and applications. These products combine complete stainless steel construction with solid state sensor technology resulting in reliable, cost effective performance. AMETEK, PMT Products Group, 820 Pennsylvania Blvd. Feasterville, PA 19053. Tel: 215-355-6900; Fax: 215-355-2937.

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AMETEK, Process & Analytical Instruments Division
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HIGH TEMPERATURE SILICA TEXTILES

Haveg high temperature textiles are available in fabric rolls, sleeving, rope, tape, and mat configurations. Many applications in aerospace, shipbuilding, foundry, power generation, and other industries. Free brochure provides complete data. 900 Greenbank Road, Wilmington, DE 19808. Tel: 302-995-0400. Fax: 302-995-0491.

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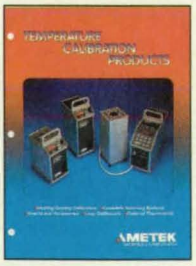


CALIBRATE TEMPERATURE ACCURATELY

FREE bulletin spotlights complete line of dry block temperature calibrators (ranges from -58 °F to 253 °F through 392 °F to 2200 °F), loop calibrators, calibration systems and accessories; also lists applications, product specifications/dimensions. 8600 Somerset Drive, Largo, FL 34643. Tel: 813-536-7831. Fax: 813-539-6882.

AMETEK, Mansfield & Green Division
For More Information Write In No. 392

Linear Motion Systems

New 100-page guide features complete product and engineering information for selection, ordering and installation of pre-engineered, pre-assembled Thomson systems. Covered are precision, ready-to-install systems available with single or parallel shafts, with or without table tops, or with shafts aligned in parallel. Data describes Powerslide* slide-drive-control systems, Superslide* ball screw-actuated systems, and Twin Shaft* slide systems.

Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

For More Information Write In No. 520

Linear Bearings and Components

Complete catalog of Thomson linear bearing systems features Ball Bushing* bearings; XR* extra-rigid Ball Bushing bearings; Roundway* linear roller bearings; 60 Case* hardened and ground LinearRace* shafting, instrument and metric bearings; pillow blocks; shaft supports; seals; and bearing accessories. Sections cover travel life, load capacities, shaft mounting and alignment, clearance, installation and lubrication.

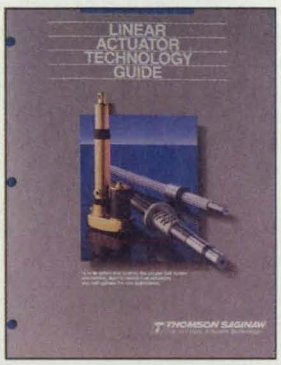
Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

For More Information Write In No. 527

Ball Screws

This 44-page guide is a complete source of information on Thomson Saginaw* ball screw actuators including rolled thread assemblies, precision ground thread assemblies, electromechanical linear actuators and ball splines. It includes product descriptions, applications, specifications, design and selection criteria and mounting instructions.

Thomson Saginaw Ball Screw Co.,
628 N. Hamilton, Saginaw,
MI 48602.
(517-776-5111)



For More Information Write In No. 522

Engineered Polymer Bearings

Designer's guide includes new technical data to make it easy to select, specify and apply Thomson Nyliner* bearings. It includes Nyliner bearing descriptions, application examples, dimensional drawings, specifications and test data, and installation and operating information. Guide also contains section on new Nyliner Plus* family of bearings made of advanced thermoplastics.

Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

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Steel Shafting

Complete specifications help readers select and apply 60 Case* hardened and ground LinearRace* shafting from 1/16 - 4 in. diameter. Shafting covered provides straightness, hardness and smoothness needed for optimum Thomson system performance. Specifications include Rockwell 60-65C hardness, straightness 0.001-0.002 in./ft., and 10-16 in. rms finish. Included are machining standards, applications, mounting, and installation.

Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

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NEW AccuGlide/AccuMax

AccuGlide* Ball Bearing Systems provide high load capacities in all directions. Applications include lathes, milling machines and machining centers. For wafer processing equipment, optical insertion equipment and electronic instrumentation, consider AccuGlide Miniature Systems. AccuMax* Roller Bearing Systems offer up to twice the load capacity of equal-sized ball bearing systems for dramatic improvement in system life, and reduction in maintenance.

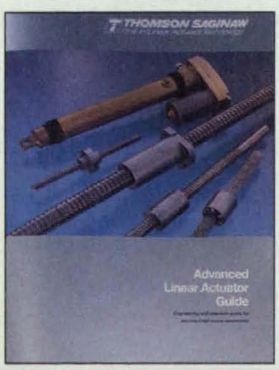
Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

For More Information Write In No. 523

NEW Metric Ball Screws

New Engineering design and selection guide for Thomson Saginaw* metric precision ball screw assemblies. Provides complete information on Precision and Precision Plus* metric ball screws, including product specifications, design and selection criteria, mounting instructions, and applications. Catalog also describes related products and services such as Performance Pak* Actuators, end machining, and repair/reconditioning services.

Thomson Saginaw Ball Screw Co., 628 N. Hamilton, Saginaw, MI 48602. (517-776-5111)



For More Information Write In No. 526

Metric Components

This catalog provides design and ordering information on Thomson Industries' full range of metric linear motion components. Products include Super Plus* Ball Bushing* bearings and pillow blocks, Roundway* II bearings, 60 Case* hardened and ground LinearRace* shafting, and accessories. Complete engineering support information is included.

Thomson Industries,
Port Washington, NY 11050.
(1-800-554-8466)

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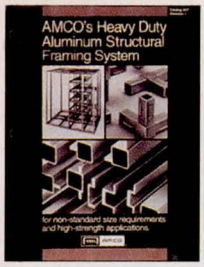

HEAVY DUTY ALUMINUM STRUCTURAL SYSTEM

AMCO offers Heavy Duty Aluminum Structural System for complex design applications. Easy to assemble, welding not required. The system includes high-strength extruded tubing with different integral flange configurations. 3 types of accessory mounting channels; 8 joining and corner castings and more.

AMCO Engineering Company

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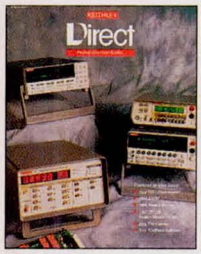
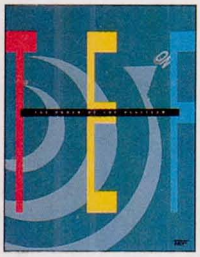


NEW KEITHLEY-DIRECT CATALOG

Keithley Instruments is offering its new direct marketing catalog of selected test instruments and accessories. Many of the company's DMMs, switches, source-measure units and accessories are included. One of the featured products in this issue is a new electrometer. Call 1-800-552-1115 for your free copy. *Keithley Instruments, Inc. 28775 Aurora Rd., Solon, OH 44139*

Keithley Instruments, Inc.

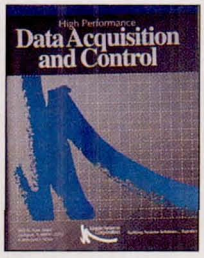
For More Information Write In No. 408



DSP-EQUIPPED ANALYZERS

Color brochure provides detailed overview of DSP-equipped acoustical analyzers with information on how to obtain a free demo disk and specific application information. The TEF20 platform combines specialized software with a PC to perform accurate electroacoustical tests.

Techron—TEF Products
1718 West Mishawaka Road, Elkhart, IN 46517
Tel: 219-294-8295.
For More Information Write In No. 411



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FREE 100+ page book from experts in test and measurement field. Topics include: What bus structure do you really need (VXI, VME, CAMAC...)?; Data quality: how good is good enough?; Antialias filtering: what are the trade-offs?; All 16-bit systems are not created equal; Software wars—test plans in 5 minutes?

KineticSystems Corporation
Tel: 800-DATA-NOW; Fax: 815-838-4424
For More Information Write In No. 414

Physical Sciences

Noncontact Electromagnetic Vibration Source

Metal aircraft skins can be scanned rapidly in vibration tests.

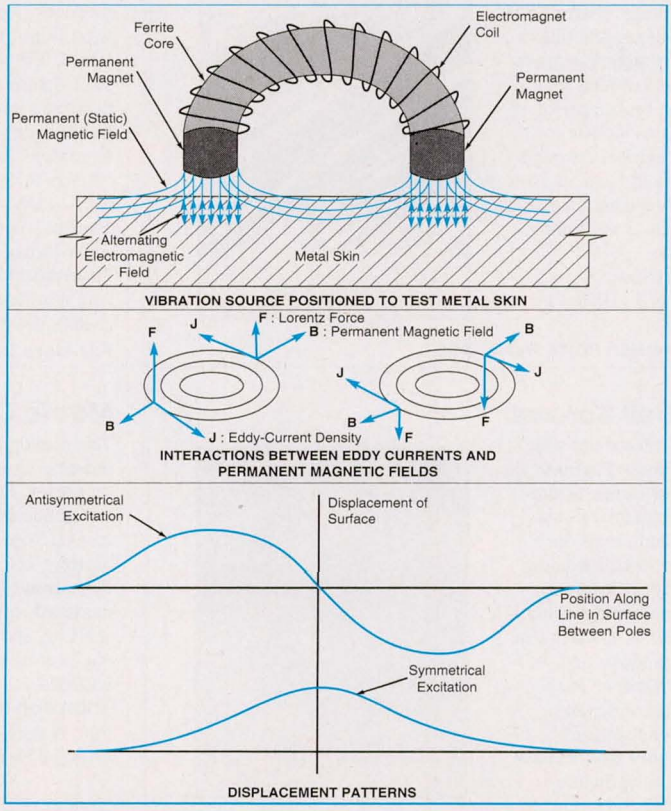
Langley Research Center, Hampton, Virginia

A relatively simple combination of permanent magnets and an electromagnet serves as a noncontact vibration source for nondestructive testing of metal aircraft skins. In a nondestructive test of this kind, the source excites vibrations, and the vibration waveforms are measured, then analyzed for changes in resonances that signify cracks and other flaws. Unlike older contact electromagnetic vibration sources that included permanent magnets attached to the skins under test, this noncontact source can be scanned rapidly across the skins.

As shown in the top part of the figure, the source includes an electromagnet coil wound on an inverted U-shaped ferrite core. Permanent magnets (e.g., cobalt/samarium) are attached to the core to produce a static magnetic field. The faces of the permanent magnets are made convex to spread out the static magnetic fields so that when the source is brought close to a metal skin, the static magnetic field lines have substantial components in the surface plane of the skin that radiate outward from the surface spots that face the magnetic poles. The ends of the ferrite core are made concave to keep the electromagnetic field lines that enter the surface as nearly perpendicular as possible to the surface.

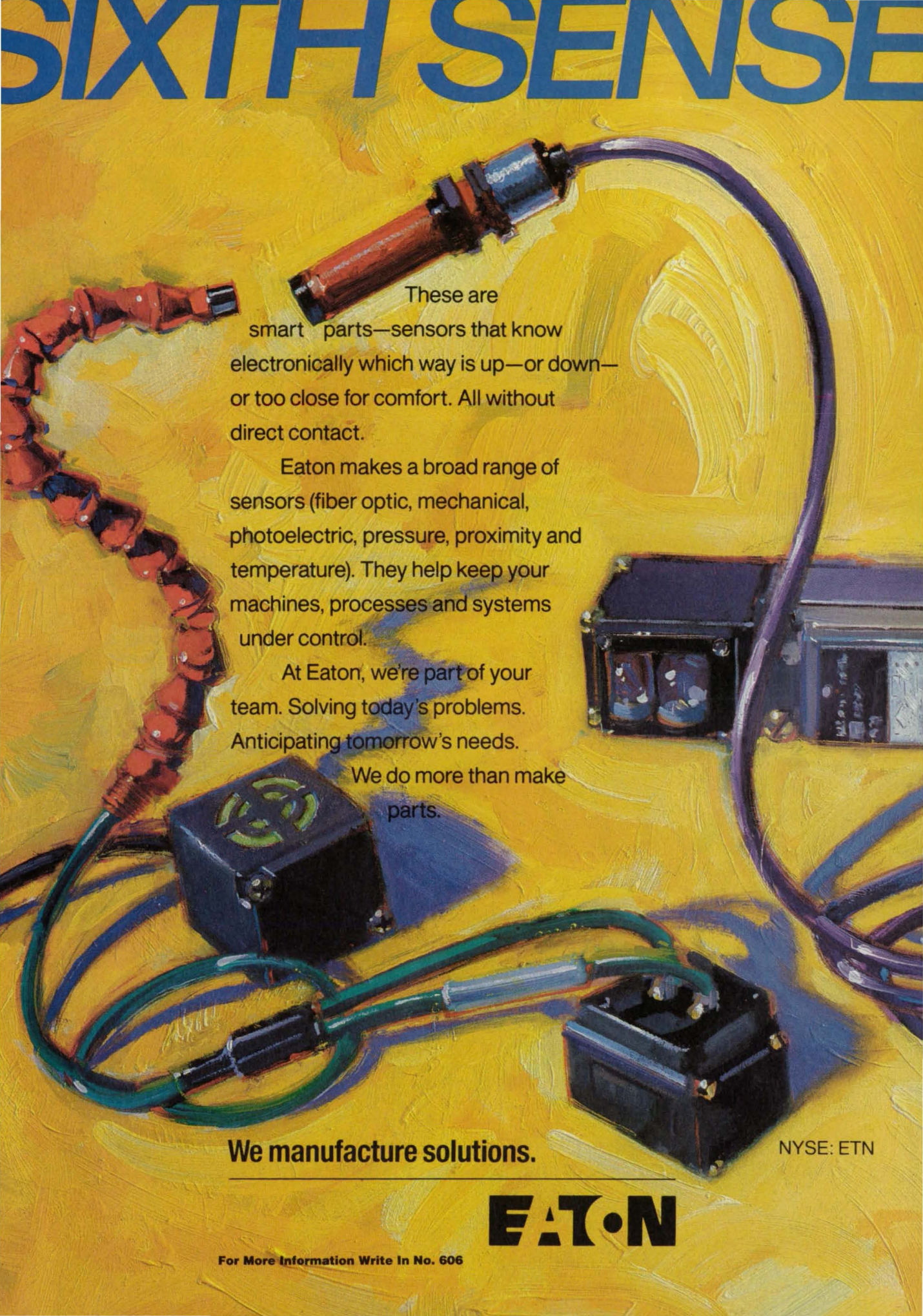
The electromagnet coil is excited with a sinusoidal or other suitable waveform to generate an alternating electromagnetic field, which induces eddy currents in the metal skin. In the magnetic-field configuration described above, the eddy currents flow approximately circularly, in and near the surface plane, around the spots that face the poles, as shown in the middle part of the figure. The eddy currents interact with the outward-radiating components of the static magnetic fields, the resulting Lorentz force being perpendicular to the surface plane of the skin. This force causes the desired vibration.

The direction of the force (into or out of the skin) exerted by each pole



The **Electromagnet Induces Eddy Currents** that interact with the permanent magnetic field to produce forces perpendicular to the surface of the metal skin. By choice of the relative polarities of the permanent magnets, the forces can be made parallel (for symmetrical excitation) or antiparallel (for antisymmetrical excitation).

SIXTH SENSE



These are smart parts—sensors that know electronically which way is up—or down—or too close for comfort. All without direct contact.

Eaton makes a broad range of sensors (fiber optic, mechanical, photoelectric, pressure, proximity and temperature). They help keep your machines, processes and systems under control.

At Eaton, we're part of your team. Solving today's problems. Anticipating tomorrow's needs.

We do more than make parts.

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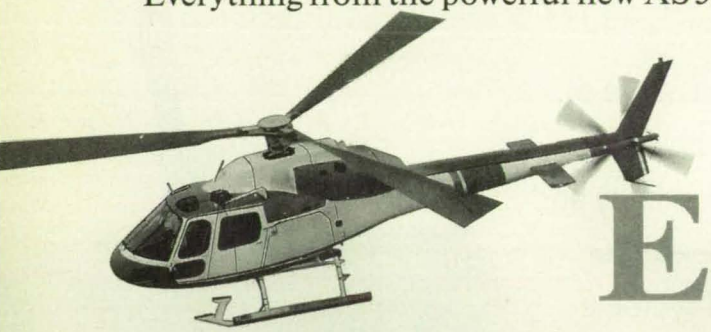

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PEMA 28

For More Information Write In No. 654

depends on the relative directions of the eddy currents and the static magnetic fields. Thus, by suitable choice of the polarities of the permanent magnets, both poles can be made to push or pull simultaneously to produce a symmetrical excitation, or else one can be made to push while the other pulls to produce an antisymmetrical excitation, as shown in the bottom part of the figure.

This work was done by Min Namkung of **Langley Research Center** *and James P. Fulton and Buzz A. Wincheski of Analytical Services and Materials, Inc.*

For further information, ***write in 104*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14914.

Temperature-Control Apparatus for Hydrogen Maser

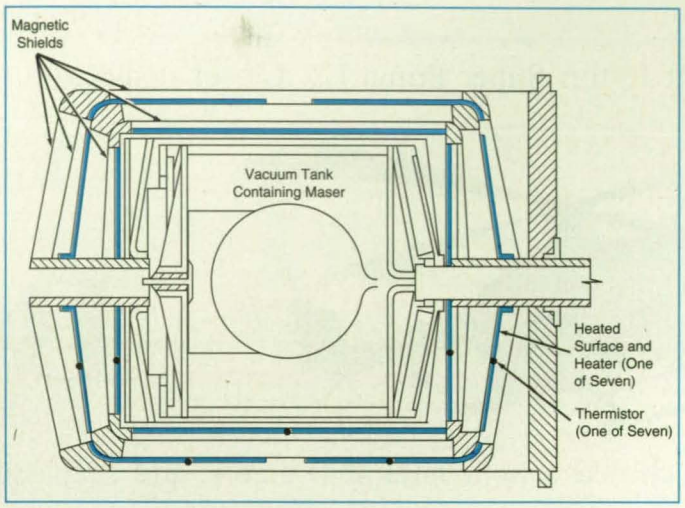
A maser can be operated in air with acceptable thermal stability.

Marshall Space Flight Center, Alabama

A thermal-control apparatus maintains a hydrogen maser at nearly constant temperature (typically, 20 or 25°C) during a long-term operational test. More specifically, the apparatus is designed to maintain, in a small cylindrical vacuum tank that contains the maser, a nearly isothermal condition (at the chosen operating temperature) when the test is conducted in air. The apparatus provides an approximation of the more nearly isothermal condition (within ±10–3°C) that is expected to be maintained in the intended application, in which the maser would be operated in a vacuum environment and losses of heat would be reduced further by multilayer reflective insulation.

The apparatus (see figure) includes three heaters mounted on the vacuum tank: one on each end and one on the side. Two outer end and two outer side heaters surround the vacuum tank and its heaters, forming an outer oven. A thermistor measures the temperature of each heated surface and thereby provides temperature feedback. Thus, there are seven heaters and the associated thermistors, which define seven thermal-control zones.

The heaters are connected mechanically to supports for magnetic shields, and the heaters and magnetic shields are arranged in interleaved layers. The spaces between the layers are filled with multilayer reflective insulation. In air, the multilayer insulation is much less effective than it is in vacuum, and the flow of heat through this insulation in air is comparable to that through the other parts of the maser structure. The outer heaters make up for the heat thus lost, thereby helping to stabilize the temperature.



The **Temperature-Control Apparatus**, shown here in simplified form, is integrated with the maser structure. Two layers containing heaters and thermistors are interleaved with magnetic shields and with reflective multilayer insulation, which is omitted for clarity.

This work was done by R. F. C. Vessot and E. M. Mattison of the Smithsonian Astrophysical Observatory for **Marshall Space Flight Center.** *For further information,* ***write in 81*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-26222.

Two-Zone Bridgman Furnace With Sharp Thermal Gradient

Temperature gradients up to 125 °C/cm can be achieved in the crystal-growth region.

NASA's Jet Propulsion Laboratory, Pasadena, California

A two-zone vertical directional-solidification furnace has been designed and built to grow crystals from stoichiometric and nonstoichiometric melts and from solutions. The furnace includes a conventional wire heater in the lower zone, a tubular silicon carbide heating element in the upper zone, and a thermal baffle between the zones (see figure).

The furnace provides a sharp vertical gradient of temperature between the two zones: a gradient of 42°C/cm has been achieved, and gradients of as much as 125°C/cm are anticipated. Crystals grow in this temperature-gradient region, and a sharper gradient enables both faster growth and better separation between solid and liquid.

The furnace can be used in a laboratory or industrial setting for growth of crystals from congruently melting materials as well as for growth of compounds formed by peritectic reactions.

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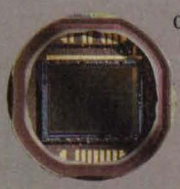

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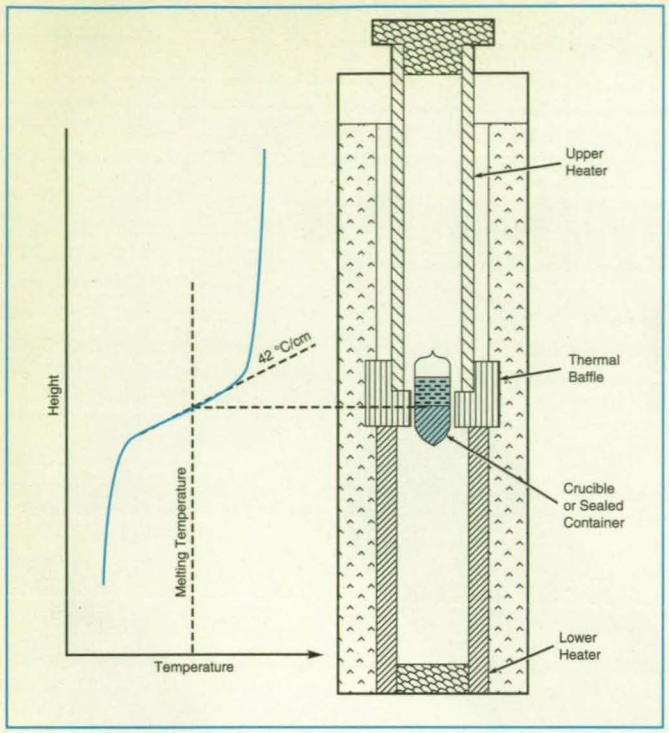

This **Two-Zone Bridgman Furnace** provides a sharp gradient of temperature for faster directional solidification and better separation between solid and liquid.

are 1,400°C in the upper zone and 1,000°C in the lower zone. An axial orifice in the thermal baffle accommodates a crucible or sealed container that contains the material to be grown. The baffle helps to prevent intensive convection of air (or other gas) between the upper and lower zones; such convection can uncontrollably change the gradient of temperature. The containers used in initial experiments had diameters no greater than 12 mm, and the heights of the melts in the containers ranged from 30 to 40 mm.

During crystallization, the container remains stationary while the temperatures in the two zones are decreased by a temperature-control circuit with feedback from a differential thermocouple. The controller decreases the temperatures with time in such a way as to maintain the gradient of temperature constant during the crystal-growth process. The typical temperature profile shown in the figure was measured by placing a monitoring thermocouple in the middle of a mockup of a crucible during calibration of the furnace.

The furnace has been used to grow very unusual peritectically formed compounds from melt solutions. Because of the sharp gradients of temperature, the separation from solution of single crystals of such grown materials as Cr11Ge19 and RuSb2 was perfect.

This work was done by Alex Borshchevsky, Thierry Caillat, and Jean-Pierre Fleurial of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 74*** *on the TSP Request Card.*
NPO-18813

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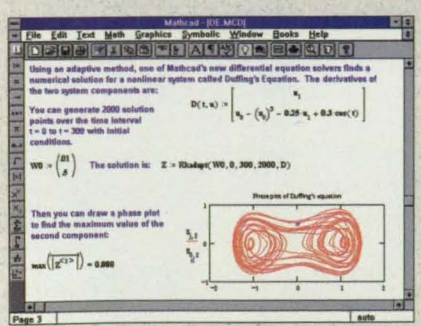

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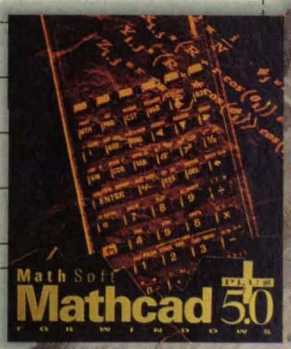

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For More Information Write In No. 650

Lightweight Electrode for Nickel/Hydrogen Cell

A nickel/hydrogen cell using nickel-fiber electrodes doubles the specific energy per unit weight of the state-of-the-art cell.

Lewis Research Center, Cleveland, Ohio

An improved substrate for a nickel electrode increases the specific energy of a nickel/hydrogen cell. The substrate consists of 50 percent by weight nickel fiber, 35 percent nickel powder, and 15 percent cobalt powder. Porosity and thickness of nickel electrodes affect the specific energy, initial performance, and cycle life of the nickel/hydrogen cell. One advantage of the nickel-fiber substrate over the state-of-the-art (SOA) nickel substrate it replaces is that the new nickel-fiber substrate can be easily manufactured with much larger porosities than those of the heavy-sintered SOA nickel substrate. The nickel fiber structures are commercially available in porosities up to 98 percent, while SOA nickel substrates are available in porosities of 80 to 86 percent.

An electrode made with the improved substrate can be discharged deeply (by 40 percent or more of the electrode capacity). It weighs less than does the heavy-sintered SOA nickel substrate, which is the heaviest component in a nickel/hydrogen cell. As a result, a cell built around the lightweight substrate has a specific energy 2.0 times that of a cell built around the heavy-sintered SOA nickel substrate.

The improved substrate is electrochemically impregnated with the nickel hydroxide active material in an aqueous solution of nickel nitrate, cobalt nitrate, and sodium nitrite. The electrode thus formed is conditioned by seven charge/discharge cycles in a 26-percent solution of potassium hydroxide. The electrode acquires a nickel hydroxide load of at least 1.6 grams per cubic centimeter of its void volume.

Initial performance and cycle life testing of a boilerplate nickel/hydrogen cell, at a 40-percent depth-of-discharge, using a nickel fiber electrode, is very promising. The nickel electrode was made from a thick [80 mil (2.0 mm)] and highly porous (90-percent) nickel-fiber substrate.

This work was done by Doris L. Britton of ***Lewis Research Center****. For further information,* ***write in 77*** *on the TSP Request Card. LEW-15053*

Spherical Perfluoropolyethers

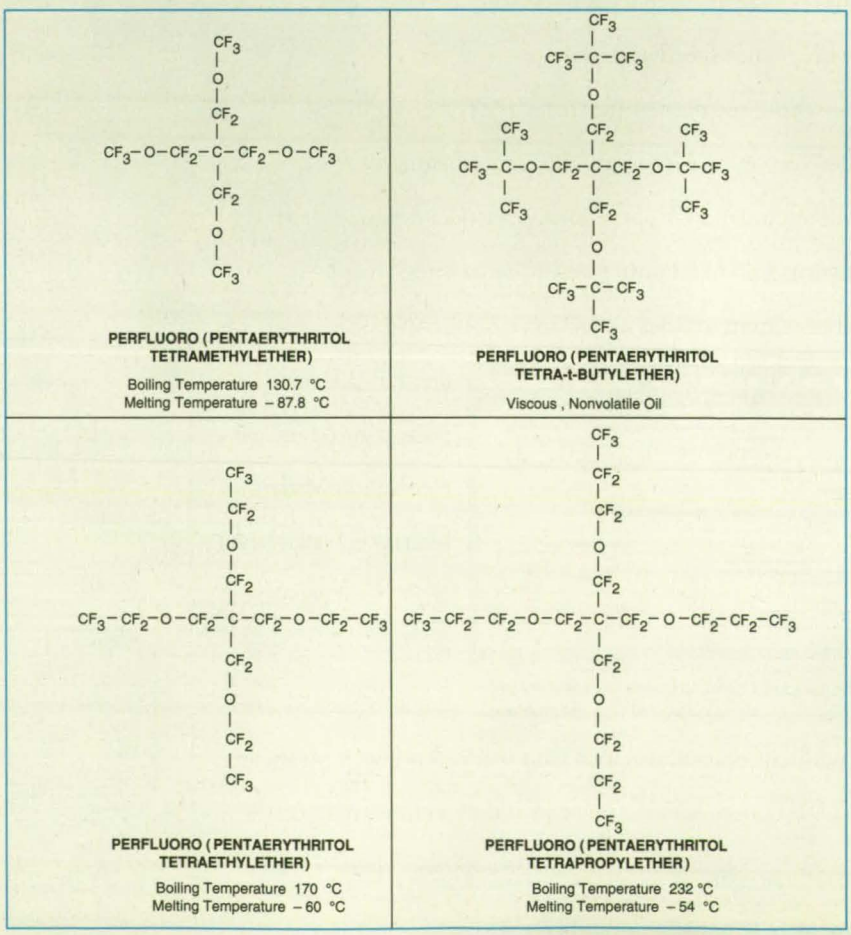
These "molecular ball bearings" may offer high thermal stability and lubrication properties.

Lewis Research Center, Cleveland, Ohio

Four fluorocarbon compounds of the generic class C(CF2OR)4 [where R = CF3, C(CF3)3, CF2CF3, or CF2CF2CF3] (see figure) have been synthesized by direct fluorination of the corresponding hydrocarbons. The molecules of these compounds are approximately spherical and may act as "molecular ball bearings." In addition to their potential utility as lubricants, these compounds are expected to be thermally stable and useful as heat-transfer fluids or even vapor-phase-soldering fluids.

This work was done by Richard J. Lagow of the University of Texas at Austin for ***Lewis Research Center***. For further information, ***write in 85*** on the TSP Request Card.

LEW-15151



These **Four Perfluorinated Ethers** may have potential as lubricants, heat-transfer fluids, and/or vapor-phase-soldering fluids.

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Low-Toxicity PMR Polyimide

This readily processed, high-performance resin is made with a less toxic diamine.

Langley Research Center, Hampton, Virginia

PMR-type polyimides formed by in situ polymerization of monomer reactants constitute an important class of ultra-high-performance composite matrix resins. Composite materials made of these resins reinforced by graphite fibers are being used increasingly in various aircraft engine components, which operate at temperatures that range from 232 to 371°C for long times. PMR-15 (15 stands for a formulated molecular weight of 1500 between cross-links) is the best-known and most-widely-used PMR polyimide. Its attributes include relatively easy processing, substantially lower costs, and excellent retention of properties at elevated temperatures. This material is prepared from an alcohol solution of three monomers: the monomethyl ester of 5-norbornene-2,3-dicarboxylic acid (NE), 4,4'-methylenedianiline (MDA), and the dimethyl ester of 3,3',4,4'-benzophenonetetracarboxylic acid (BTDE).

However, in recent years, the health and safety problems posed by MDA and polymers derived from this diamine have become of great concern. On the basis of extensive test data, the National Institute of Occupational Safety and Health recommends that MDA be considered a potential occupational carcinogen, making PMR-15 less acceptable. Attempts have been made to replace the MDA in PMR-15 with a less toxic diamine. However, none of the resulting products demonstrates the desired combination of characteristics, such as ease of processing and high retention of mechanical properties at elevated temperatures.

A new, low-toxicity PMR system has been developed at NASA Langley Research Center and designated LaRC-RP46. This system incorporates 3,4'-oxydianiline (3,4'-ODA), which has been found to exhibit no detectable mutagenicity. LaRC-RP46 is a substantially improved high-temperature PMR system that exhibits better processability, toughness, and thermo-oxidative stability than does PMR-15, and has a low toxicity. LaRC-RP46 is prepared by reacting NE, 3,4'-ODA, and BTDE (see figure). Besides being potentially less toxic than MDA, 3,4'-ODA contains an ether linkage coupled with a meta isometric amine group, which causes it to be extremely flexible. When this flexible diamine is incorporated into the backbone of the PMR polyimide, the resin exhibits good flow properties, which, in turn, improve processability. This polyimide is extremely stable, and its flexibility imparts toughness.

This polyimide is relatively inexpensive and readily processed into a high-quality graphite-fiber-reinforced composite. The composite material retains excellent mechanical properties at 316°C, even after service for several hundred hours, and at 371°C. This new material can be used as a high-performance, high-temperature-resistant adhesive, molding, composite, film, and coating material where low toxicity is a desired characteristic. It should significantly extend the applications of PMR-type polyimides.

This work was done by Ruth H. Pater, Robert M. Ely, Clarence E. Stanfield, George E. Dickerson, and John J. Snoha of **Langley Research Center;** Krishna

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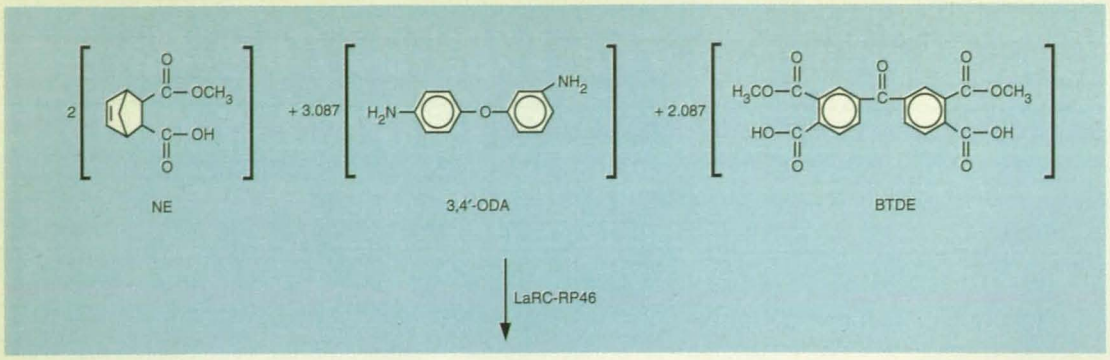


The **High-Performance Polyimide LaRC-RP46** is made with 3,4′-ODA, which is less toxic than was the MDA used to make PMR-15 polyimide.

Srinivasan of Old Dominion University; and Tan Hou of Lockheed Engineering & Sciences Co. For further information, ***write in 39*** on the TSP Request Card.

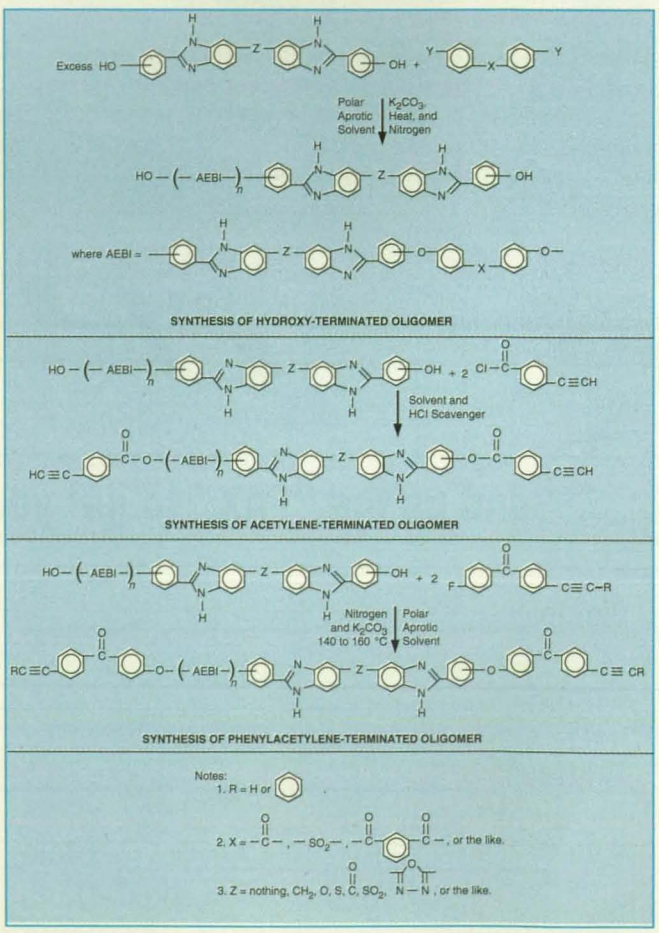
This invention has been patented by NASA (U.S. Patent No. 5,171,822). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20].

Refer to LAR-14639.

Acetylene- and Phenylacetylene-Terminated Poly(Arylene Ether Benzimidazole)s (PAEBI's)

These polymers have properties superior to those of many other high temperature polymers including other PAEBI's.

Langley Research Center, Hampton, Virginia



Acetylene- and Phenylacetylene-Terminated PAEBI Oligomers are synthesized in these reaction sequences.

Acetylene(ethynyl)- and phenylacetylene(phenylethynyl)-terminated arylene ether benzimidazole polymers can be prepared by first synthesizing polymers terminated with hydroxy groups, then reacting them with either 4-ethynylbenzoyl chloride or 4-fluoro-4′-phenylethynylbenzophenone (see figure). The endcapped polymers are subsequently thermally cured to yield materials with an attractive combination of properties. In comparison with analogous PAEBI's of high molecular weight and other high-temperature polymers, the cured acetylene- and phenylacetylene-terminated PAEBI's exhibit higher glass-transition temperatures and accordingly better retention of mechanical properties at high temperatures. The cured acetylene- and phenylacetylene-terminated polymers exhibit excellent adhesion to copper foil and polyimide film. These materials are potentially useful as adhesives, coatings, composite matrices, fibers, films, membranes, and moldings.

The glass-transition temperatures of cured benzimidazole-, acetylene-, and phenylacetylene-terminated PAEBI's of comparable molecular weights having the same thermal history were 273, 291, and 307 °C, respectively. The cured acetylene- and phenylacetylene-terminated polymers had glass-transition temperatures significantly higher than those of the cured benzimidazole-terminated polymers, presumably due to higher crosslink density. Thin-film properties at elevated temperature followed the same trend as did the glass-transition temperatures. Unoriented thin films [2 mils (0.05 mm) thick] of the benzimidazole-, acetylene-, and phenylacetylene-terminated PAEBI's cured under the same conditions exhibited about the same tensile strength and modulus at 23 °C, with values of about 17,000 psi (117 MPa) and 540,000 psi (3.8 GPa) respectively. The 23 °C elongation was 25 percent for the benzimidazole-terminated polymer and 11 percent for the acetylene- and phenylacetylene-terminated polymers, again

reflecting the effect of higher crosslink density. A significant difference was observed when the films were tested at 250 °C. The films of the acetylene- and phenylacetylene-terminated polymers exhibited tensile strengths and moduli with values of 10,000 psi (69 MPa) and 300,000 psi (2.1 GPa) at 250 °C, respectively, significantly higher than the films of the benzimidazole-terminated polymers. The film of the benzimidazole-terminated polymer gave elongation of 55 percent at 250 °C, more than twice the values obtained for the films from the acetylene- and phenylacetylene-terminated polymers.

The synthetic route to the acetylene- and phenylacetylene-terminated PAEBI's is depicted in the figure. The top portion of the figure shows the synthesis of the precursor hydroxy-terminated arylene ether benzimidazole polymer. This material is subsequently reacted with 4-ethynylbenzoyl chloride to yield the acetylene-terminated PAEBI or with 4-fluoro-4′-phenylethynyl benzophenone in the presence of potassium carbonate at 140–160 °C in a polar aprotic solvent to provide the phenylacetylene-terminated PAEBI.

This work was done by John W. Connell and Paul M. Hergenrother of **Langley Research Center** *and Joseph G. Smith, Jr., of the University of Akron. For further information,* ***write in 50*** *on the TSP Request Card.*

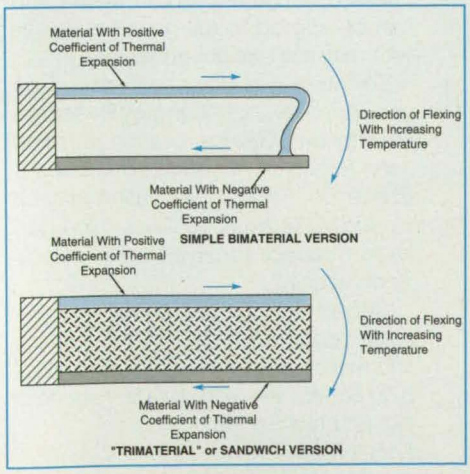
Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14965.

Bimaterial Thermal Strip With Increased Flexing

The active materials would have opposite coefficients of thermal expansion.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed modification of the basic concept of the bimetallic strip would make the strip flex more with a given change in temperature. The modified bimetallic strip would be a bimaterial strip, in which one of the two metal layers of the bimetallic strip would be replaced by a material that has a negative coefficient of thermal expansion (see figure). Known materials that have negative coefficients of thermal expansion that could be used in the proposed bimaterial strips include



In a **Proposed Bimaterial Thermal Strip**, one layer would have a negative coefficient of thermal expansion, thereby increasing the difference between the coefficients of thermal expansion of the two outer layers and consequently increasing the flexing caused by a change in temperature.

spodumene (LiAlSi2O6) and spodumene-based ceramics. The proposed bimaterial strips could be used in thermostats, for example.

Because metals have positive coeffiallic strips, which contain metals that have different coefficients of thermal expansion, may not flex enough, or with enough force, to meet the requirements for certain applications. By replacing one metallic layer in such a strip with a layer that has a negative coefficient of thermal expansion, one can increase the difference between the coefficients of thermal expansion of the two layers, thus increasing the extent and the force of the flexing caused by a change in temperature.

In the basic bimaterial version of the proposed strip, the two materials — one with a positive coefficient of thermal expansion and the other with a negative coefficient of thermal expansion — would simply be directly connected to each other, as shown in the figure. In a "trimaterial" or sandwich version, a material with little stiffness and/or a coefficient of thermal expansion close to zero would be sandwiched between a metallic layer (with its positive coefficient of thermal expansion) and a layer with a negative coefficient of thermal expansion. Other versions may also be feasible.

This work was done by Andrew D. Morrison of Caltech for **NASA's Jet Propulsion Laboratory**. For further information, ***write in 84*** on the TSP Request Card. *NPO-18848*

Thin CVD Coating Protects Titanium Aluminide Alloys

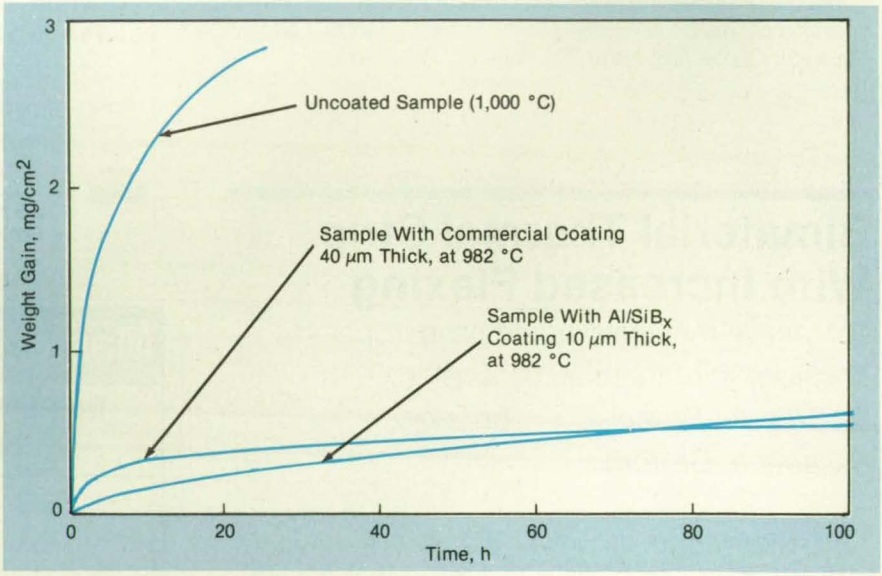
Low catalytic activity and good protection against oxidation are obtained.

Langley Research Center, Hampton, Virginia

The useful characteristics of titanium aluminide alloys, candidate materials for use in structures and heat shields on hypersonic vehicles, are limited by the responses of these materials to the hypersonic environment. Thermal-control coatings on the surfaces of these materials are needed to lower temperatures of the vehicles by radiating heat from the surfaces and by minimizing the catalytic heating caused by recombination of dissociated molecular species at the surfaces. At high temperatures, titanium aluminides are susceptible to environmental degradation in the form of oxidation and embrittlement. Therefore, these coatings must also provide shielding of the substrate alloys.

Investigations were conducted into titanium aluminide alloys with and without coatings for thermal control and/or protection against the environment. Baseline performances were defined in the cases of three titanium aluminide alloys: Ti/14Al/21Nb (α_2), Ti/14Al/19Nb/3V/2Mo (super-α2), and Ti/33Al/6Nb/1.4Ta(γ). Static oxidation tests were conducted with the three alloys in air, using the thermogravimetric analysis to obtain weight-gain data at temperatures up to 1,000 °C. Coated and uncoated samples were exposed to simulated hypersonic flight conditions for as long as 5 hours at a surface temperature of 982 °C to determine their catalytic efficiencies. Post-test evaluations included measurements of radiative properties to determine emittance, plus metallurgical evaluations to determine oxide phases and microstructural changes.

A 10-μm-thick Al/SiB_x coat produced by physical vapor deposition and chemical vapor deposition (CVD) performed very well under simulated hypersonic flight conditions and showed promise as a barrier against oxygen. The catalytic efficiency of the coating is about 0.02, which is lower than that of any coating previously evaluated. The change in the weight of an Al/SiB_x-coated α2 sample in oxidation for 100 h at 982 °C compares favorably with that of an α_2 sample covered with a much thicker commercially available diffusion coating (see figure).



The **Weight Gained in Oxidation,** an inverse indicator of the protection against oxidation, was measured on one coated and two coated α_2 specimens. The Al/SiB_x coat provided the best protection (lowest weight gain) for more than 80 h.

The feasibility of using very thin CVD coatings to provide both protection against oxidation and surfaces of low catalytic activity for thin metallic heat-shield materials has been demonstrated. The use of aluminum in the compositions increases the emittances of the coatings and reduces the transport of oxygen through the coatings to the substrates. These coatings are light in weight and can be applied to foil-gauge materials with minimum weight penalties.

This work was done by Ronald Clark and Terryl Wallace of **Langley Research Center** *and George Cunnington and John Robinson of Lockheed Missiles & Space Co. Further information may be found in AIAA paper 90-1742, "Non-Catalytic Coatings for Hypersonic Vehicle Applications."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York 10019, Telephone No. (212) 247-6500.

LAR-14381

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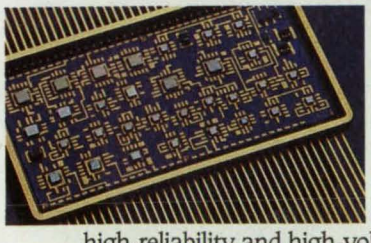

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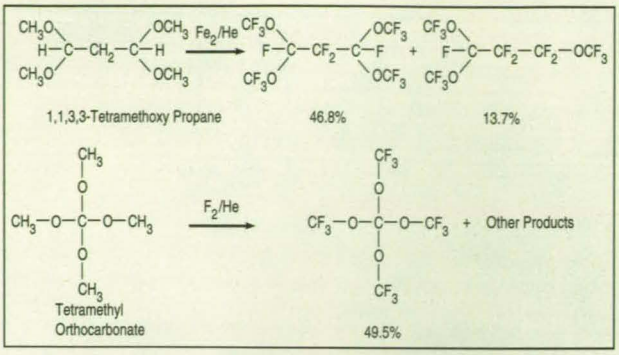
Synthesis of Perfluoro Orthocarbonates

These novel, thermally stable compounds were prepared by direct fluorination.

Lewis Research Center, Cleveland, Ohio

Perfluoro tetraalkyl orthocarbonates and perfluoro dialkyl acetals have been synthesized by direct fluorination of orthocarbonates and polyalkoxy propanes (see figure). These new perfluoro compounds are far more volatile than are the perfluoropolyethers that have the same molecular weights and are stable at temperatures up to at least 150 °C. They might be useful as heat-exchange fluids, lubricants, and/or vapor-phase soldering fluids.



These **Chemical Reactions** are typical of the class of reactions described in the text.

In preparation for a typical experimental synthesis, a mixture of measured amounts of starting orthocarbonate or acetal with approximately 10 g of powdered NaF was packed in a copper tube, which was then placed in the first zone of a four-zone cryogenic reactor. The last three zones were packed with fluorinated copper turnings. After all zones were cooled to –100 °C or –120 °C for 2 h, the system was flushed with helium for 10 h. The fluorination was then carried out by passing a time-varying mixture of He and F_2 gases through the reactor, the zones of which were maintained at various time-varying temperatures from –100 °C or –120 °C to ambient.

As the reaction was completed, the products were fractionated into sequential traps at temperatures of –78, –131, and –196 °C, respectively, on a vacuum line. The majoriy of the product was obtained in the –78 °C trap. Final purification was done by gas chromatography, using a fluorosilicone column.

The products were identified by elemental analysis, nuclear-magnetic-resonance spectroscopy of ^{19}F, mass spectrometry, and infrared spectroscopy. The perfluoro tetraalkyl orthocarbonates and dialkyl acetals were found to decompose in hydrogen fluoride solution and concentrated hydrochloric acid but to be stable in concentrated sulfuric and nitric acids.

This work was done by Richard J. Lagow and Wen-Huey Lin of the University of Texas for **Lewis Research Center**. *For further information,* ***write in 60*** *on the TSP Request Card.*
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Mathematics and Information Sciences

General-Purpose Plotting Software

TADPLOT makes it easy to generate publication-quality plots from numerical data.

The TADPLOT computer program was developed to give the researcher a general-purpose plotting software package that is easy to use, can quickly create X–Y plots, and is powerful enough to create full-feature publication-quality plots. Such a package gives the researcher control over the content and layout of each image, and delivers publication-quality plots quickly. With TADPLOT integrated into an applications software network, researchers can view experimental (or theoretical) results immediately after collection. The underlying graphics software package enables the user to save selected plot information that can be displayed subsequently on several different devices, including "hard-copy" plotters. Postprocessing features that enable the user to manipulate and combine plots are also available.

TADPLOT is coordinated by a single easy-to-use interface, enabling the re-

searcher to gain access to several standard file formats, collect selectively specific subsets of data, and create full-featured publication-quality plots. The user interface was designed to be independent of any file format, yet provide capabilities to accommodate highly specialized data queries. With TADPLOT integrated into an applications software network, data can be retrieved, collected, and viewed quickly and easily.

DI-3000 from Precision Visuals, Inc. is used as the underlying graphics software for TADPLOT. TADPLOT generates external files (called metafiles), which can be postprocessed by use of the Metafile Translator in DI-3000. The same DI-3000 metafile can be displayed on several different devices.

TADPLOT is written in ANSI STANDARD FORTRAN 77 for CRAY-series computers running UNICOS, and CONVEX C-series computers running CONVEX OS. No binaries are included with this distribution. TADPLOT requires the DI-3000 Graphics package from Precision Visuals, Inc. With minor modifications, TADPLOT can be installed on any UNIX system that supports the DI-3000 Graphics software package. This program is available on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in UNIX tar format (standard distribution medium). It is also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. TADPLOT was developed in 1991.

This program was written by Dana P. Hammond of Computer Sciences Corp. for **Langley Research Center**. *For further information,* ***write in 55*** *on the TSP Request Card.*
LAR-14846

Raster Metafile and Raster Metafile Translator Programs

The Raster Metafile program is meant to help standardize the representation of raster image data.

There is an ever-growing demand for graphical depiction of numerical results to aid visualization in a scientific computing environment. Along with this demand, there has emerged an associated demand for one or more portable device-independent graphical output formats. Developed at NASA's Langley Research Center (LaRC), the Raster Metafile (RM) computer program is a generic raster-image-format program, and the Raster Metafile Translator (RMT) program is an assortment of software tools for processing images prepared in this format.

The problem of processing raster image data in LaRC's computing environment can be characterized by an increasing number of software-package-specific raster data formats that are to be displayed on an increasing number of raster devices that accept only device-specific raster data input. As a consequence, there has been a proliferation of data-translator computer programs that convert package-specific raster output into device-specific raster input. To minimize translation of raster data, LaRC has adopted a generic RM format and developed an RMT for processing RM-formatted image data. The Raster Metafile program is the product of an attempt by LaRC to standardize the representation of raster image data. The generation and processing of raster image data can be simplified greatly by adoption of the RM format.

The specification of a generic raster image format does not eliminate the requirement for conversion of the data format. It remains necessary to convert package-specific data into RM format and to convert RM data into device-specific data.

However, software tools are provided to simplify the conversion from package-specific formats to RM format. In addition, translation from RM format to a device-specific format is simplified through the invocation of a collection of software device drivers, including a device-driver template.

RMT is a command-driven program with the primary function of processing RM-formatted raster image data. RMT processing includes reading, writing, and displaying RM images. Such other image-manipulation features as a minimal compositing operator and a resizing option are available under the RMT command structure.

The RMT is written in FORTRAN 77 and C language for Sun4-series computers running SunOS and CONVEX C-series computers running CONVEX OS. No binaries are included with this distribution. RMT requires 2.5 Mb of random-access memory for execution. The following is a list of supported output devices: CELCO film recorders, PostScript and color PostScript printers, Tektronix 4109 and 4125 terminals, Sun color and monochrome workstations, and Versatec ECP-42 and thermal plotters. The standard distribution medium for RMT is a 9-track, 1,600-bit/ in. (630-bit/cm) magnetic tape in UNIX tar format. It is also available on a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. RMT was developed in 1989 and was first released in 1992.

This program was written by Donald P. Randall, Raymond L. Gates, and Kristi M. Skeens of Computer Sciences Corp. for **Langley Research Center**. *For further information,* ***write in 99*** *on the TSP Request Card.* LAR-14114

Resupply Scheduler Program Using Integer Optimization

Lifetimes of components, assembly schedules, and other constraints are taken into account.

Resupply Scheduling Modeler (RSM) is a fully menu-driven computer program that uses integer programming techniques to determine an optimum schedule for replacing components on or before the ends of fixed replacement periods. Although written to analyze the electrical power system on the Space Station Freedom, RSM is quite general and can be used to model the resupply of almost any system subject to user-defined constraints on resources.

RSM is based on a specific form of the general linear-programming problem in which all variables in the objective function and all variables in the constraints are integers. While more computationally intensive, integer programming was required for accuracy when modeling systems that contain small numbers of components. Input values for the lifetimes of components can be real numbers. RSM converts them to integers by dividing the lifetimes by the durations of the replacement periods, then reducing the results to the next lowest integers. For each component, there is a set of constraints that ensure that it is replaced before its lifetime expires.

RSM includes such user-defined constraints as transportation mass and volume limits as well as lifetimes of components, available repair-crew time, and assembly sequences. A weighting factor enables the program to minimize such factors as cost. The program then performs an iterative analysis, which is displayed during processing. A message gives the first period in which resources are being exceeded on each iteration. If the scheduling problem is unfeasible, the final message also indicates the first period in which resources are exceeded.

RSM is written in APL2 for IBM PC-series and compatible computers. A stand-alone executable version of RSM is provided; however, this is a "packed" version of RSM that can uti-

lize only the memory within the 640K DOS limit. This executable code requires at least 640K of memory and DOS 3.1 or higher. Source code for an APL2/PC workspace version is also provided. This version of RSM can make full use of any installed extended memory but must be run with the APL2 interpreter; it requires an 80486-based microcomputer or an 80386-based microcomputer with an 80387 math coprocessor, at least 2 Mb of extended memory, and DOS 3.3 or higher. The standard distribution medium for this package is one 5.25-in. (13.34-cm), 360K MS-DOS format diskette. RSM was developed in 1991.

APL2 and IBM PC are registered trademarks of International Business Machines Corp. MS-DOS is a registered trademark of Microsoft Corp.

This program was written by L. A. Viterna of **Lewis Research Center** *and D. M. Reed of Wittenberg University. For further information,* ***write in 75*** *on the TSP Request Card. LEW-15309*

Computer Program Helps Enhance Images

Pixel Pusher works with color images digitized to 8 bits.

Pixel Pusher is a Macintosh application program for viewing and performing minor enhancements on imagery. It reads image files in JPL's two primary image formats — VICAR and PDS — as well as in the Macintosh PICT format. VICAR (NPO-18076) handles an array of image-processing capabilities that may be used for a variety of applications, including processing of biomedical images, cartography, imaging of Earth resources, and geological exploration. Pixel Pusher can also import color lookup tables in VICAR format for viewing images in pseudocolor (256 colors).

This program currently supports only 8-bit images but works on monitors with any number of colors. Arbitrarily large image files can be viewed in a normal Macintosh window. Enhancement of color and contrast can be performed with a graphical "stretch" editor (as in contrast stretching). In addition, VICAR images can be saved as Macintosh PICT files for export to other Macintosh programs, and individual pixels can be queried to determine their locations and actual data values.

Pixel Pusher is written in Symantec's Think C and was developed for use on

a Macintosh SE30, LC, or II-series computer running System Software 6.0.3 or later and 32-bit QuickDraw. Pixel Pusher runs only on a Macintosh computer that supports color (whether or not a color monitor is in use). The standard distribution medium for this program is a set of three 3.5-in. (8.89-cm) diskettes in Macintosh format. The price of the program includes documentation. Pixel Pusher was developed in 1991.

Think C is a trademark of Symantec Corp. Macintosh is a registered trademark of Apple Computer, Inc.

This program was written by Daniel F. Stanfill, IV, of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 72*** *on the TSP Request Card.*
NPO-18635

MATH77, Version 4.0

This is a collection of programs that are used repeatedly in science and engineering.

MATH77 is a high-quality library of ANSI FORTRAN 77 subprograms that implement contemporary algorithms for the basic computational processes of science and engineering. The portability of MATH77 meets the needs of scientists and engineers who typically use a variety of computing environments. Release 4.0 of MATH77 contains 454 user-callable and 136 lower-level subprograms. Usage of the user-callable subprograms is described in 69 sections of the 416-page user's manual.

The topics covered by MATH77 are indicated by the following list of chapter titles in the user's manual: Mathematical Functions, Pseudo-random Number Generation, Linear Systems of Equations and Linear Least Squares, Matrix Eigenvalues and Eigenvectors, Matrix Vector Utilities, Nonlinear Equation Solving, Curve Fitting, Table Look-Up and Interpolation, Definite Integrals (Quadrature), Ordinary Differential Equations, Minimization, Polynomial Rootfinding, Finite Fourier Transforms, Special Arithmetic, Sorting, Library Utilities, Character-based Graphics, and Statistics.

Besides subprograms that are adaptations of public-domain software, MATH77 contains a number of unique packages of software developed by the authors of MATH77. Instances of the latter type include (1) adaptive quadrature, allowing for exceptional generality in multidimensional cases, (2) an algorithm that solves ordinary differential equations and that has been used in computing trajectories of spacecraft for JPL missions, (3) univariate and multivariate table lookup and interpolation, allowing for "ragged" tables, and providing estimates of errors, and (4) univariate and multivariate derivative-propagation arithmetic.

MATH77 release 4.0 is a subroutine library that has been carefully designed to be usable on any computer system that supports the full ANSI standard FORTRAN 77 language. It has been successfully implemented on a CRAY Y/MP computer running UNICOS, a UNISYS 1100 computer running EXEC

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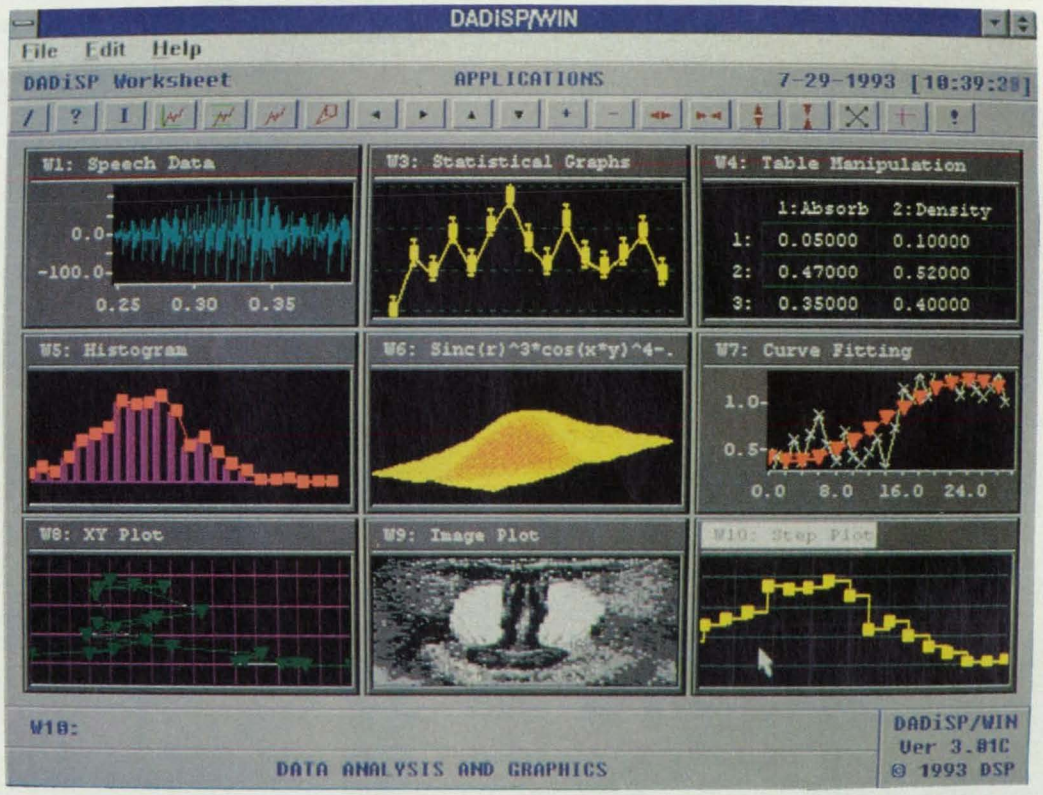

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For More Information Write In No. 648

8, a DEC VAX-series computer running VMS, a Sun4-series computer running SunOS, a Hewlett–Packard 720 computer running HP-UX, a Macintosh computer running MacOS, and an IBM PC-compatible computer running MS-DOS. Accompanying the library is a set of 196 "demo" drivers that exercise all of the user-callable subprograms.

MATH77 comprises 109K lines of FORTRAN source code in 375 files with a total size of 4.5 Mb. The demo drivers occupy 11K lines of code with a total size of 418K. Forty-four percent of the lines of the library code and 29 percent of those in the demo code are comment lines. The standard distribution medium for MATH77 is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. It is available on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape in VAX BACKUP format and a TK50 tape cartridge in VAX BACKUP format.

Previous releases of MATH77 have been used over a number of years in a variety of JPL applications. MATH77 Release 4.0 was completed in 1992. MATH77 is a copyrighted work with all copyright vested in NASA.

This program was written by Charles L. Lawson, Fred Krogh, W. Van Snyder, Carol A. Oken, Faith A. McCreary, Jay H. Lieske, Jack Perrine, Ralph S. Coffin, and Warren J. Wayne of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 68*** *on the TSP Request Card.*
NPO-18918

Machinery

Analyzing Thermal Conditions in Rocket Engines

RTE computes three-dimensional temperature profiles in the cooling jacket wall.

Currently, high-pressure rocket thrust chambers are being designed to be reusable, In order to create a durable design, an accurate prediction of the temperatures within the cooling-jacket wall is necessary. Since large thermal gradients are present in the wall during operation, a new computer code, RTE, has been developed to perform three-dimensional thermal analyses of rocket thrust chambers. RTE calculates the rate of heat transfer from the combustion gases to the coolant, the coolant-temperature rise and pressure drop, and temperature profiles within the cooling-jacket wall. This program can be used for any propellant combination and most coolants that are commonly used in rockets.

Input data files for RTE contain the composition of the fuel/oxidant mixture and rates of flow, chamber pressure, temperature and pressure of the coolant at the entrance, dimensions of the engine materials, and the number of nodes in different parts of the engine. RTE includes subroutines that evaluate the thermodynamic and transport properties of both the combustion gases and the coolant, while another subroutine evaluates the nodal distribution of temperature. These calculations are made for each iteration and are given as part of the output.

RTE also calculates the combustion-gas wall static pressure, temperature and enthalpy, as well as the coolant pressure, temperature, and mach number for all stations. This code can be used for both regeneratively and radiatively cooled engines. However, in the case of regeneratively cooled

engines, its applicability is limited to those engines that feature single-pass cooling and rectangular cooling channels. All inputs and outputs of the program are in the English system of units.

RTE is written in FORTRAN for DEC VAX-series computers running VMS. The program requires 2 Mb of virtual memory for execution. This program is available in DEC VAX BACKUP format on a 9-track, 1,600-bit/in. (630-bit/cm) magnetic tape (standard distribution medium) or on a TK50 tape cartridge. RTE was released in 1991.

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This program was written by M. H. N. Naraghi of Manhattan College for **Lewis Research Center**. *For further information,* ***write in 51*** *on the TSP Request Card. LEW-14941*

Computing Flows of Coolants in Turbomachines

CPF computes the flow in a one-inlet/one-outlet passage of any shape.

A computer code has been developed to predict accurately the coolant flow and heat transfer inside turbomachinery cooling passages (either radial or axial blading). The computer program Coolant Passage Flow (CPF) resulted from a joint NASA Lewis and Army Propulsion Directorate effort to design, build, and test a cooled radial turbine.

CPF analyzes a turbomachinery coolant-flow path that has any size and shape and that consists of one passage with a single inlet and outlet. Flow can be bled off for tip-cap impingement cooling, and one can specify a flow bypass in which a flow of coolant can be taken out and reintroduced at a point farther downstream in the passage.

CPF calculates the rate of flow of coolant, the temperature, the pressure, the velocity, and the heat-transfer coefficients along the passage. It integrates the one-dimensional momentum and energy equations along a defined flow path, taking into account the change in area, addition or subtraction of mass, pumping, friction, and transfer of heat. The user can choose the rate of flow of coolant or let the program compute it from the specified inlet and outlet conditions. The flow must be subsonic everywhere, but it can be choked at the main and bypass exits, as well as at the tip-cap inlet and outlet. CPF predictions show good agreement with closed-form solutions for isentropic flow, Fanno-line flow, and Rayleigh-line flow.

CPF is written in FORTRAN IV and was originally developed for an AMDAHL computer running VM; however, the program has been executed successfully on a variety of other computers. With little or no modification, this program should run successfully on any computer with a FORTRAN compiler that supports NAMELIST. The main memory requirement for running CPF on a DEC VAX computer running VMS is 165K. The program source code and sample input and output are provided with the program. CPF is available on a 9-track, 1,600-bit/in. (630-bit/ cm) BPI ASCII CARD IMAGE magnetic tape (standard distribution medium) or a 5.25-in. (13.34-cm), 360K diskette in MS-DOS format. This program was developed in 1990.

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This program was written by P. L. Meitner of Army Propulsion Directorate, located at the **Lewis Research Center.** *For further information,* ***write in 17*** *on the TSP Request Card. LEW-15180*

Analyzing Flows in Rocket Nuclear Reactors

CAC computes aspects of the flows of fluid and heat.

One of the most important factors in the design of a nuclear rocket engine is to be able to predict the temperatures and pressures throughout a fission nuclear reactor core with axial flow of hydrogen along circular coolant passages. CAC is an analytical prediction program to study the heat-transfer and fluid-flow characteristics of a circular coolant passage. CAC predicts, as a function of time, the axial and radial fluid conditions, temperatures of passage walls, rates of flow in each coolant passage, and approximate maximum material temperatures.

CAC incorporates the hydrogen-properties mathematical model of the STATE computer program to provide fluid-state relations, thermodynamic properties, and transport properties of molecular hydrogen in any fixed ortho/para combination. The program requires the general core geometry, the properties of the core materials as functions of temperature, the core power profile, and the core inlet conditions as functions of time.

Although CAC was originally developed in FORTRAN IV for use on an IBM 7094 computer, this version is written in ANSI standard FORTRAN 77 and is designed to be machine-independent. It has been successfully compiled on IBM PC-series and compatible computers running MS-DOS with Lahey F77L, a Sun4-series computer running SunOS 4.1.1., and a VAX-series computer running VMS 5.4-3. CAC requires 300K of random-access memory (RAM) under MS-DOS, 422K of RAM under SunOS, and 220K of RAM under VMS. No sample executable code is provided on the distribution medium. Sample input and output data are included. The standard distribution medium for this program is a 5.25-in. (13.34-cm), 360K diskette in MS-DOS format. CAC was developed in 1966, and this machine-independent version was released in 1992.

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This program was written by J. S. Clark and J. T. Walton of **Lewis Research Center** *and M. McGuire of the University of Cincinnati. For further information,* ***write in 98*** *on the TSP Request Card. LEW-15400*

Physical Sciences

Software for Calibration of Polarimetric SAR Data

OLCAL calibrates data supplied in Stokes-matrix format.

Calibration of polarimetric radar systems is a field of research in which great progress has been made during the last few years. POLCAL (Polarimetric Radar Calibration) is a software tool intended to assist in the calibration of synthetic-aperture radar (SAR) systems. In particular, POLCAL calibrates Stokes-matrix-format data produced as the standard product by the NASA/Jet Propulsion Laboratory (JPL) airborne imaging synthetic aperture radar (AIRSAR).

The AIRSAR is a multifrequency (wavelengths of 6, 24, and 68 cm), fully polarimetric SAR system that produces 12¥12 km imagery at 10 m resolution. AIRSAR was designed for use as a test bed for NASA's Spaceborne Imaging Radar program. While

the images produced after 1991 are thought to be calibrated (phase calibrated, crosstalk removed, channel imbalance removed, and absolutely calibrated), POLCAL can and should still be used to verify the accuracy of the calibration and to correct it if necessary.

Version 4.0 of POLCAL is an upgrade of version 2.0 of POLCAL released to AIRSAR investigators in June 1990. New options in version 4.0 include automatic absolute calibration of 89/90 data, distributed-target analysis, calibration of nearby scenes with calibration parameters from a scene with corner reflectors, altitude or roll-angle corrections, and calibration of errors introduced by known topography.

Many sources of error can lead to false conclusions about the nature of scatterers on the surface. Errors in the phase relationship between polarization channels result in incorrect synthesis of polarization states. Crosstalk, caused by imperfections in the radar antenna itself, can also lead to error. POLCAL reduces crosstalk and corrects phase calibration without the use of ground calibration equipment.

Removal of the antenna patterns during SAR processing also forms a very important part of the calibration of SAR data. Errors in the processing altitude or in the aircraft roll angle are possible causes of error in computing the antenna patterns inside the processor. POLCAL uses an altitude-error-correction algorithm to remove the antenna pattern from the SAR images correctly. POLCAL also uses a topographic-calibration algorithm to reduce those calibration errors that result from ground topography.

By utilizing the backscatter measurements from either the corner reflectors or a well-known distributed target, POLCAL can correct the residual amplitude offsets in the various polarization channels and correct for the absolute gain of the radar system. POLCAL also gives the user the option of calibrating a scene by use of the calibration results from a nearby scene. This enables precise calibration of all the scenes acquired on a flight line where corner reflectors were present. Construction and positioning of corner reflectors is covered extensively in the program documentation.

In an effort to keep the POLCAL code as transportable as possible, the authors eliminated all interactions with a graphics display system. For this reason, it is assumed that users will have their own software for doing the following: (1) synthesizing an image by use of either horizontal or vertical polarization in both transmitting and receiving, (2) displaying the synthesized image on a display device, and (3) reading the pixel locations of the corner reflectors from the image. The only inputs used by the software (in addition to the input Stokes-matrix data file) is a small data file with the corner-reflector information.

POLCAL is written in FORTRAN 77 for use on Sun-series computers running SunOS and DEC VAX computers running VMS. It requires 4 MB of random-access memory for execution. The standard distribution medium for POLCAL is a 0.25 in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. It is also available on 9-track, 1,600 bit/in. (630-bit/cm) magnetic tape in DEC VAX FILES0-11 format. Other distribution media may be available upon request. Documentation is included in the price of the program. POLCAL 4.0 was released in 1992 and is a copyrighted work with all copyrights vested in NASA.

This program was written by Jakob Van Zyl, Howard Zebker, Anthony Freeman, John Holt, Pascale Dubois, and Bruce Chapman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 70*** *on the TSP Request Card.*
NPO-18954

Retractable Rotary-Bit Tool

An allen key can be removed from the workspace.

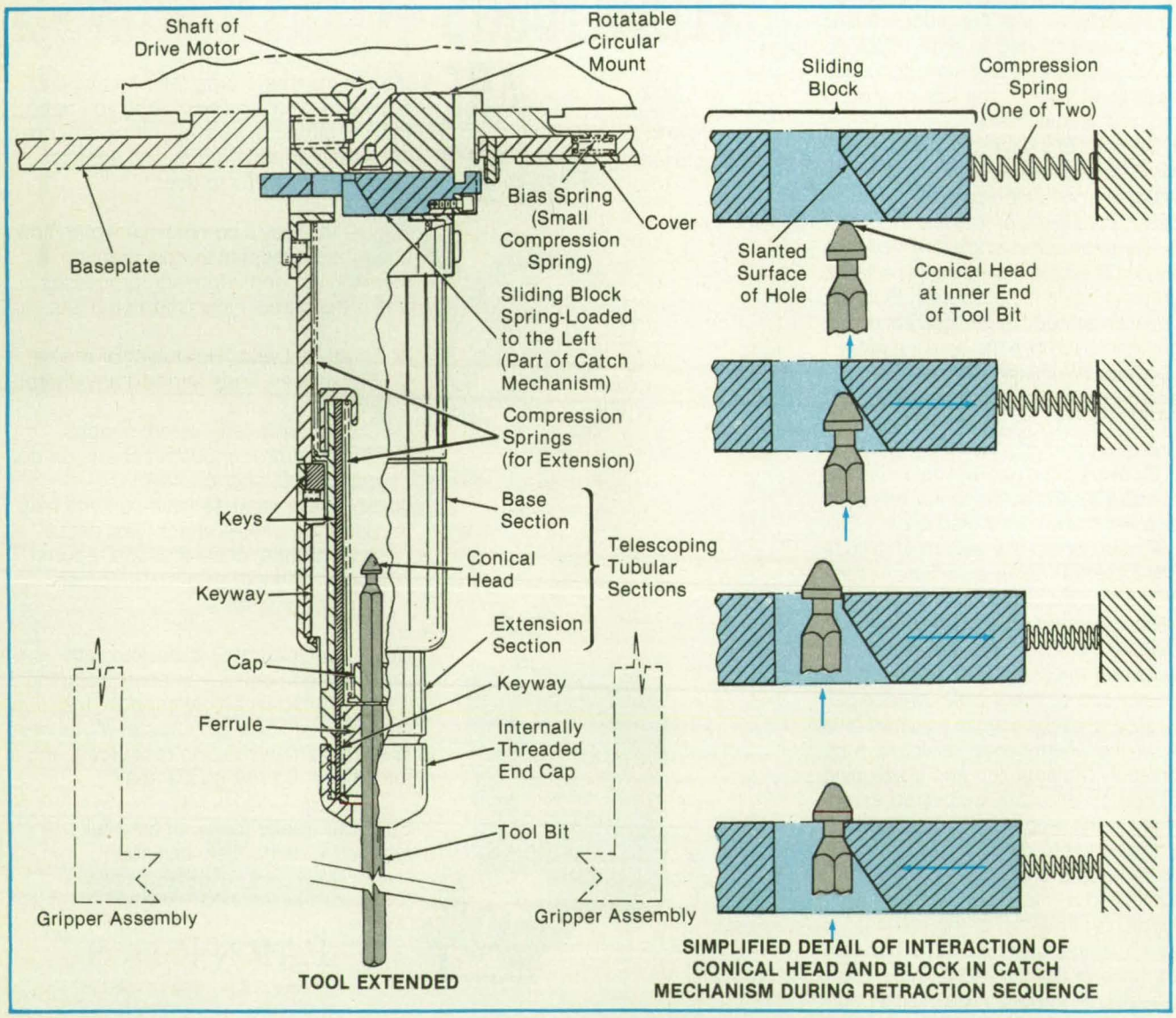
Goddard Space Flight Center, Greenbelt, Maryland

A tool designed to be part of the end effector of a robot can be retracted when it is not in use to provide clear workspace. The tool bit can be an allen key, for example.

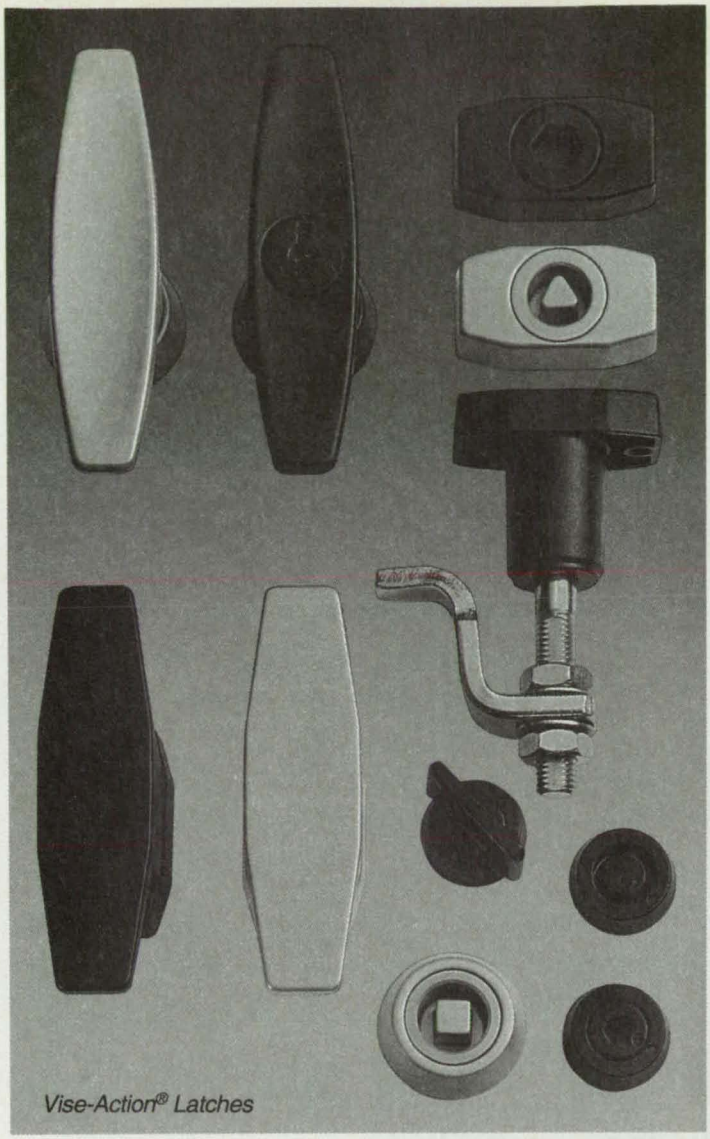
The tool includes telescoping sections that are spring-loaded toward extension. The tool also includes a catch mechanism that retains the inner end of the tool bit and keeps the tool retracted. The tool is mounted on a gripper at the end of the robot arm. The tool includes a base section (see figure), which is one of the two telescoping sections and is bolted to a rotatable circular mount. This mount, in turn, is fastened to the shaft of a drive motor. An end cap, which keeps the tool bit from falling out, is screwed onto the outer end of the extension section, which is the other of the two telescoping sections.

When the tool is extended, the motor transmits torque to the tool through keyways and keys. The tool is designed to fit loosely in the end cap to give it a small amount of compliance, which is desirable in robotic applications.

After the tool has been used, the robot pushes the outer end of the tool bit against a shallow cup, and the telescoping sections are compressed axially. As this is done, a conical head on the inner end of the tool bit makes contact with the slanting wall of a hole in a block that can slide sideways in a groove. The force of contact pushes the block sideways until the lip of the block engages the undercut shoulder of the cone. This action locks the tool in the retracted position. Thereafter, the compression



Built-in Springs extend the tool to its working position. When the tool is no longer needed, the telescoping assembly is compressed until the conical head on the inner end of the tool bit engages the lip of sliding block, latching the tool in the retracted position.



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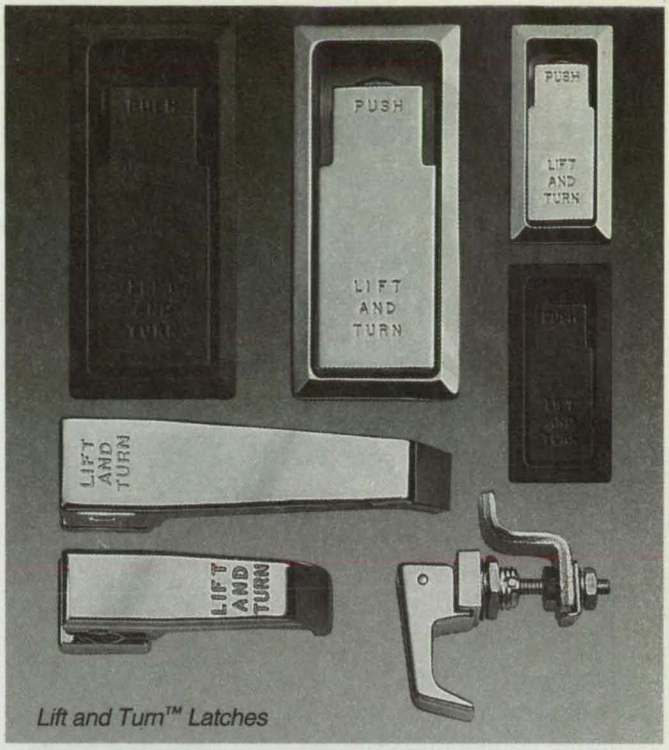

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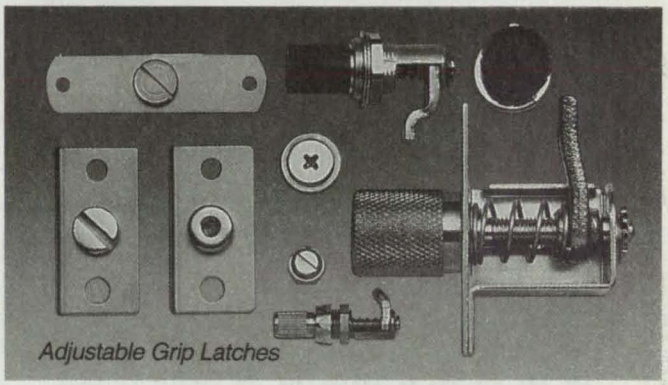

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springs that would otherwise cause extension hold the shoulder against the lip, while other compression springs force the block sideways against the narrow neck on the tool bit just below the conical head. No dedicated actuators are needed to perform the retraction; robot arm movements alone perform the task.

To reextend the tool, the rotatable circular mount is actuated by the drive shaft. By cam action, the rotation of the mount pushes the lip of the block away from the shoulder of the conical head on the tool bit. The compression springs in the telescoping sections then extend the tool to its working position.

This work was done by George Voellmer of **Goddard Space Flight Center.** For further information, ***write in 83*** on the TSP Request Card.

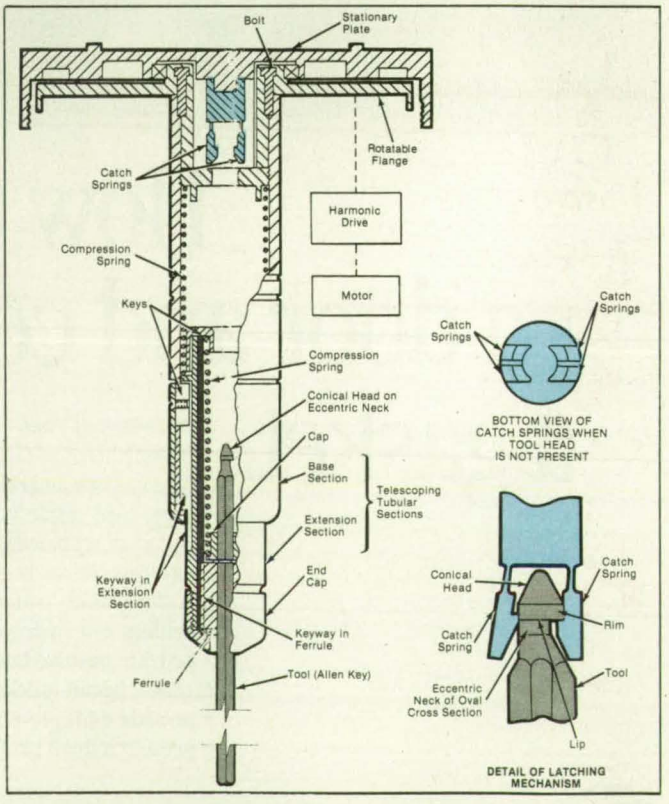
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13358.

Retractable Rotary Tool With Simplified Latch

Opposing catch springs latch onto a head, retaining the tool in retraction.

Goddard Space Flight Center, Greenbelt, Maryland

The figure shows a retractable rotary tool that is part of a robot hand. The tool is similar to the one described in the preceding article, "Retractable Rotary-Bit Tool" (GSC-



The **Conical Head** at the upper end of the tool bit is latched in the retracted position by catch springs. The eccentric neck just below the head makes it possible to release the head from the catch springs by rotating the telescoping tubular sections and tool bit.

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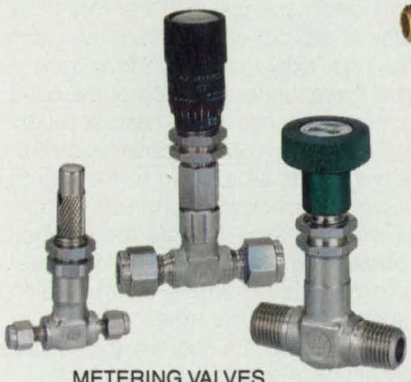

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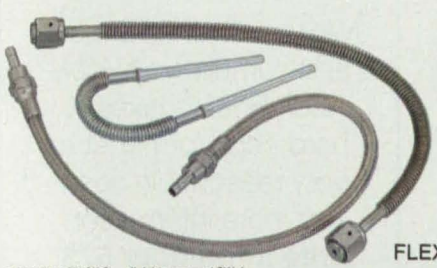

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13358), except that it includes a simpler mechanism for retention in, and release from, the retracted position.

Like the prior tool, this one includes telescoping tubular sections (see figure) and a tool bit that are spring-loaded toward axial extension. As before, the telescoping sections and tool bit are prevented from rotating with respect to each other (but allowed to move axially) by keys and mating keyways. Also as before, the base section (one of the two telescoping tubular sections) is mounted on a rotatable flange. The flange is driven by a motor and a harmonic gear drive.

The inner end of the tool bit differs from that of the prior version. It includes a conical head with a short cylindrical rim and an eccentric neck with an oval cross section. When the robot pushes the outer end of the tool against a suitable unyielding object, the tool bit and telescoping sections are forced inward against the spring bias. As this motion continues and just as the tool is about to reach the fully retracted position, the conical head pushes apart two opposing pairs of catch springs mounted on a stationary plate near the inner (upper in the figure) end of the base section. When the tool is pushed in a little farther, the lip under the rim of the conical head engages clawlike protrusions on two of the springs, and the springs snap inward. The clawlike protrusions of the left (in the figure) pair of springs are located slightly above those of the right pair of springs; this ensures that at any angle of rotation of the eccentric neck, two springs are always available to latch onto the head.

The spring catches thus retain the tool in the retracted position. To initiate release, the drive motor and harmonic drive turn the rotatable flange; this causes the telescoping sections and tool bit to rotate about the cylindrical axis, while the catch springs remain stationary. At some point during the rotation, the conical tip and eccentric neck of the tool bit pass through the angular position in which there is no lip to engage the clawlike protrusions on the catch springs, and the tool bit is free to slip out of the grip of the catch springs, axially outward (downward in the figure) under the push of the compression springs. If the head is caught on the upper pair of clawlike protrusions, it first slips down to the slightly lower pair of clawlike protrusions, then eventually slips free as the rotation passes the release point of the lower protrusions. Then the compression springs extend the telescoping tubular sections and the tool bit to the full-length working position.

This work was done by George Voellmer of ***Goddard Space Flight Center.*** *For further information,* ***write in 36*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20].
Refer to GSC-13359.

Improved All-Terrain Suspension System

A simpler linkage is proportioned to operate in sand and climb obstacles.

NASA's Jet Propulsion Laboratory, Pasadena, Californi

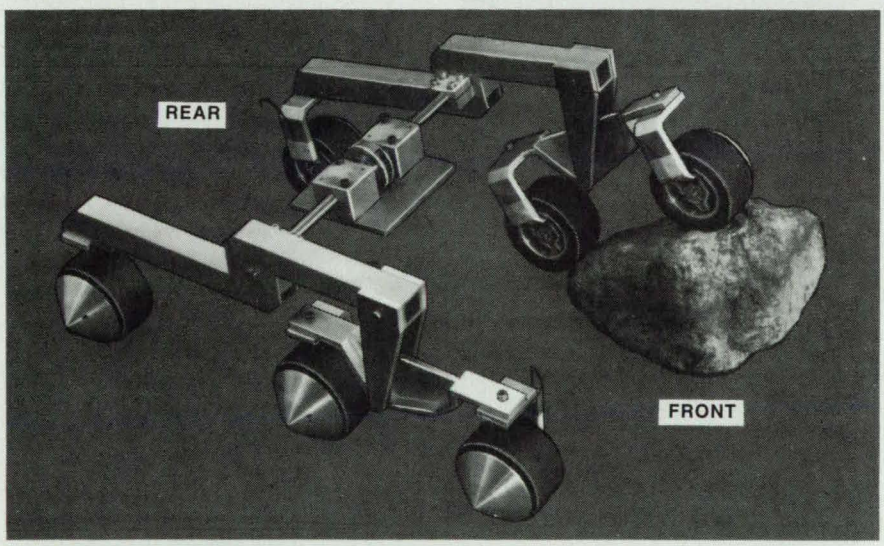
A redesigned suspension system for an all-terrain vehicle (see figure) exhibits enhanced ability to negotiate sand and rocks. Designed for a rover vehicle for exploration of Mars, the suspension also has potential application in off-road vehicles, military scout vehicles, robotic emergency vehicles, and toys.

Predecessors of this suspension system were described in "Articulated Suspension Without Springs" (NPO-17354), *NASA Tech Briefs*, Vol. 14, No. 1 (January 1990), page 60; "Four-Wheel Vehicle Suspension System" (NPO-17407), *NASA Tech Briefs*, Vol. 14, No. 8 (August 1990), page 55; and "High-Clearance Six-Wheel Suspension" (NPO-17821), *NASA Tech Briefs*, Vol. 16, No. 6 (June 1992), page 77. The six-wheel suspension described in the last-mentioned article contained a more complicated pantograph mechanism, which tended to become stalled by large rocks between the wheels.

The redesigned suspension, with a rocking bogie, is much simpler: it contains only two links per three-wheel set. A vehicle is supported by a right and a left set of three wheels connected to the body by a differential linkage. This differential mechanism stabilizes the body by averaging the tilt angles of each side.

The key to the agility of the new suspension is its relative dimensions. The proportions have been sized by computer simulations to minimize the friction required to surmount rocks and other objects. Other design tradeoffs included the placing of pivots high enough to clear objects and the enlarging of the wheels to improve performance in soft sand. The rocker bogie performs in both directions without the need to shift the center of gravity.

This work was done by Donald B. Bickler of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 86*** *on the TSP Request Card. NPO-18719*



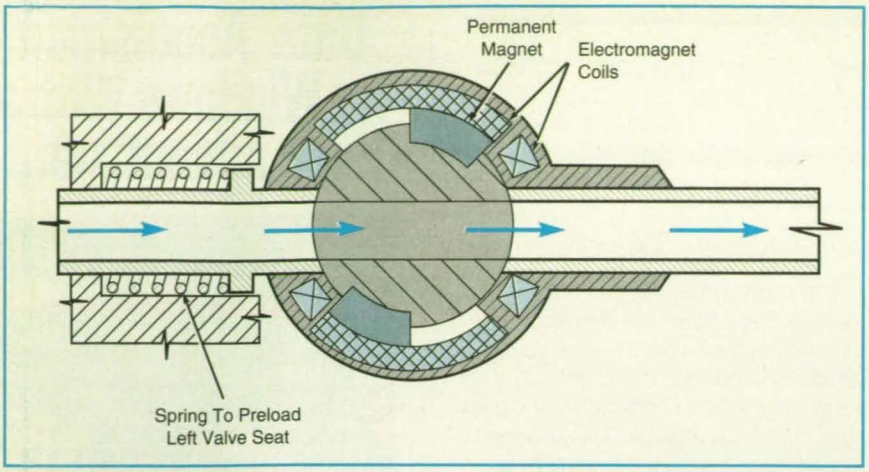
The **Improved Six-Wheel Suspension System** includes only two links on each side. The bogie tends to pull the rear wheels with it as it climbs.

Latching Solenoid-Operated Ball Valve

Electrical energy would be consumed only during opening or closing motion.

Marshall Space Flight Center, Alabama

A proposed solenoid-operated ball valve would latch in its open or closed position until it is energized to change position. The valve would consume energy only during the switching (opening or closing) interval, which would



The Ball Would Hold Permanent Magnets and would constitute a permanent-magnet armature of a rotary solenoid. The housing would contain the stator coils of the solenoid. The ball is shown here in the open position.

last no more than 40 ms. The maximum power consumed during this interval would be only 42 W.

The valve ball would contain a central channel through which fluid could flow. The ball would be made of a highly magnetically permeable steel. Permanent magnets would be mounted in recesses in the ball and would protrude from the ball (see figure). The valve housing would also be made of highly magnetically permeable steel and would contain electromagnet coils.

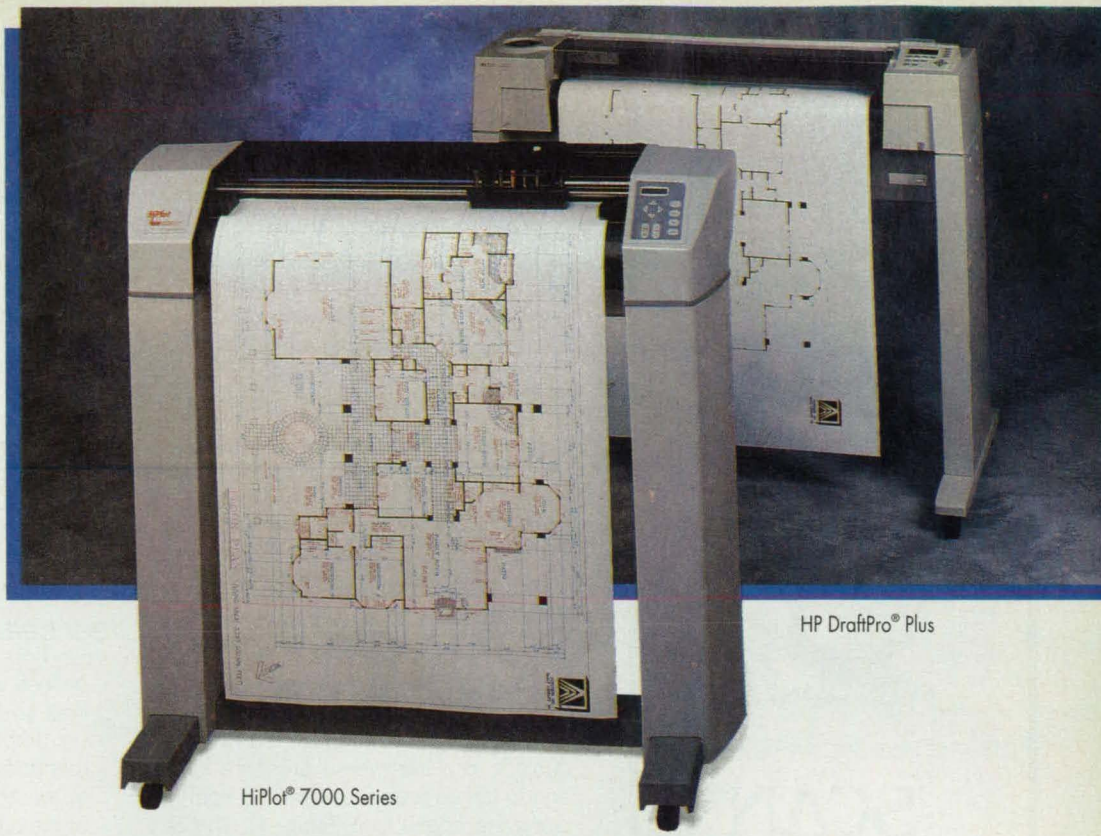
When the appropriate coil(s) were energized by a brief pulse (or pulses) of electrical current at the appropriate polarity, the ball would rotate clockwise until the permanent magnets came to rest against hard stops in the housing, and the inlet and outlet ports would be aligned with the central channel so that the fluid could flow through the valve. The magnets would adhere to the stops by magnetic attraction, thus latching the valve in the open position; no electrical current would be needed to keep the valve open.

To close the valve, the appropriate coil(s) would be energized by a pulse (or pulses) of the appropriate polarity to generate magnetic forces that would rotate the ball counterclockwise until the magnets made contact with hard stops, and the inlet and outlet ports would be sealed. As before, magnetic attraction would latch the valve in the closed position.

The angle of shutoff or turn-on rotation would be only 45°. The shortness of this rotational stroke would help to minimize wear, actuation time, and consumption of electrical energy.

The valve could be equipped with a manual override knob connected to the ball by a shaft through an O-ring seal. The knob would also indicate the position of the valve. The valve would latch in its most recent position, regardless of whether it has been moved manually or electrically.

An additional electromagnet coil would be placed near each hard stop to reduce the latching force: The coils near the stops at which the permanent magnets were latched would be energized momentarily along with the main turning coils. The fluxes generated by these coils would buck the permanent-magnet fluxes, thereby reducing the latching



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force at the old position and making it easier to turn the ball to the new position.

This work was done by Myron Brudnicki of Allied-Signal Aerospace Co. for **Marshall Space Flight Center**. *For further information,* ***write in 94*** *on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C 2457 (f)], to Allied-Signal Aerospace Company. Inquiries concerning licenses for its commercial development should be addressed to:

Terry L. Miller Patent Councel
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Refer to MFS-28715, volume and number of this NASA Tech Briefs *issue, and the page number.*

Deflection and Stress in Preloaded Rectangular Membrane

Previous calculations for a square membrane are generalized.

Goddard Space Flight Center, Greenbelt, Maryland

A theoretical analysis has yielded equations for the transverse deflection of, and stresses in, a rectangular membrane subject to a transverse pressure load and to tensile preloads applied uniformly along the edges (see Figure 1). This is an extension of the analysis reported in "Deflection and Stress in Preloaded Square Membrane" (GSC-13367), *NASA Tech Briefs*, Vol. 15, No. 9 (September 1991), page 96.

Like the previous analysis for the square membrane, this analysis follows a strain-energy/virtual-deflection approach, which is common in stress-and-strain problems of this kind. Indeed, this analysis is identical to the previous one except in the following respects:

- The assumed expressions for the stretching (in-plane deflection) and bending (out-of-plane or transverse deflection) of the membrane are modified so that the boundary conditions on displacements (zero displacements along the edges) are satisfied at the edges of the rectangle instead of the edges of the square.
- The use of the modified displacements in the strain-energy integrals results in three simultaneous nonlinear equations (instead of one in the case of the square) for the relationship among the maximum deflection at the center of the membrane, the transverse pressure load, the edge preloads, the modulus of elasticity and Poisson's ratio of the membrane material, and the thickness of the membrane.

The simultaneous nonlinear equations can be solved iteratively to obtain the in-plane and transverse displacements, then the tensile stresses in the membrane

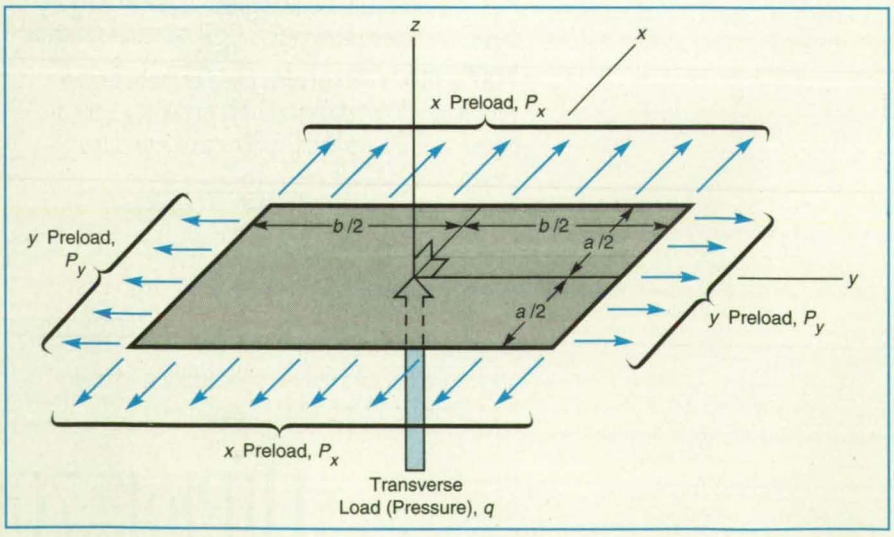


Figure 1. Uniform Stretching Preloads are applied to the edges of a rectangular membrane that is also subject to a transverse pressure load.

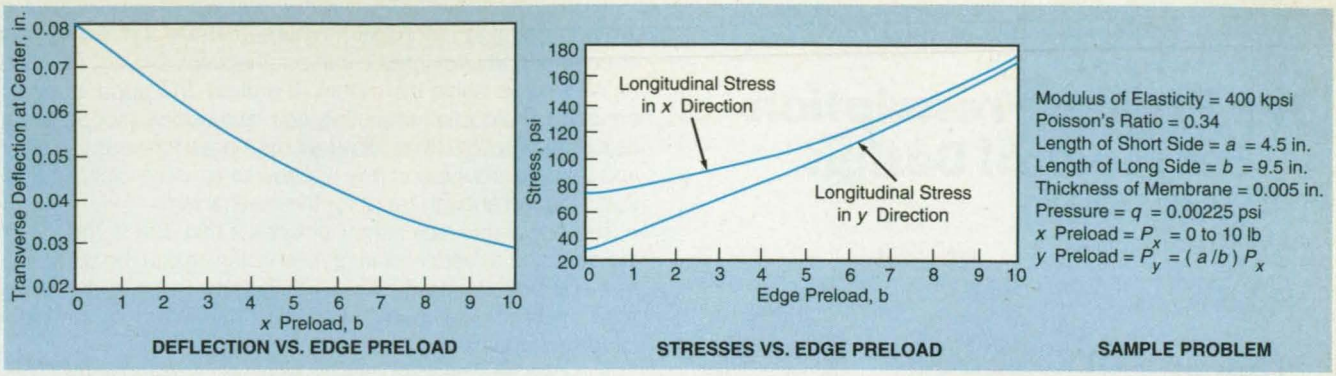


Figure 2. **Deflection and Stresses** as functions of edge preload were computed for a rectangular polyimide membrane under a fixed pressure load and a varying edge preload.

can be computed from the displacements. Figure 2 presents an example of calculations of deflections and stresses in a Kapton (or equivalent) polyimide membrane.

This work was done by Alfonso Hermida of **Goddard Space Flight Center**. *For further information,* ***write in 5*** *on the TSP Request Card.*
GSC-13561

Versatile Support for Electromagnetic-Test Model

One unit accommodates models of various sizes and shapes.

Langley Research Center, Hampton, Virginia

A supporting apparatus holds a model for measurements of its electromagnetic properties. The apparatus includes a rigid swept strut, on the end of which the model is oriented over a range of angles. The apparatus is designed to interfere minimally with the electromagnetic measurements.

Unlike an older apparatus that includes

a model-rotating mechanism mounted inside the model, this apparatus does not intrude into an unacceptably large portion of the volume inside the model. Therefore, this apparatus can be used to hold a flat, essentially two-dimensional model as well as a solid or hollow three-dimensional model, whereas the older apparatus could support only a hollow three-dimensional model that included enough room for the mechanism.

This apparatus (see figure) includes a thin disk at the top of the strut and a model-rotating mechanism inside the strut. The model is bolted onto the disk, which rests on a thrust bearing atop the strut. The model is oriented in azimuth by turning a drive shaft that is part of the mechanism.

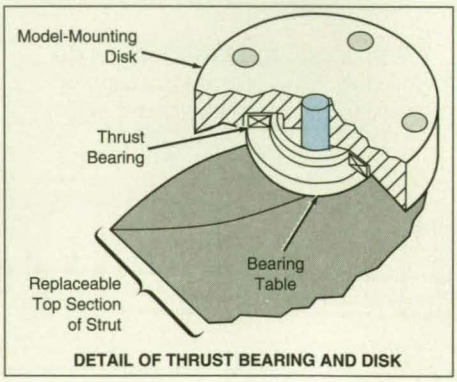
The disk and bearing can be removed and replaced. They are available in a variety of thicknesses, diameters, and load capacities to accommodate models in a range of sizes and weights.

The top section of the strut is also replaceable. The top surface of this top section is flat, and the slant of this surface determines the pitch angle of the model. Thus, the pitch angle of the model can be changed by selecting a top section that has a different slant.

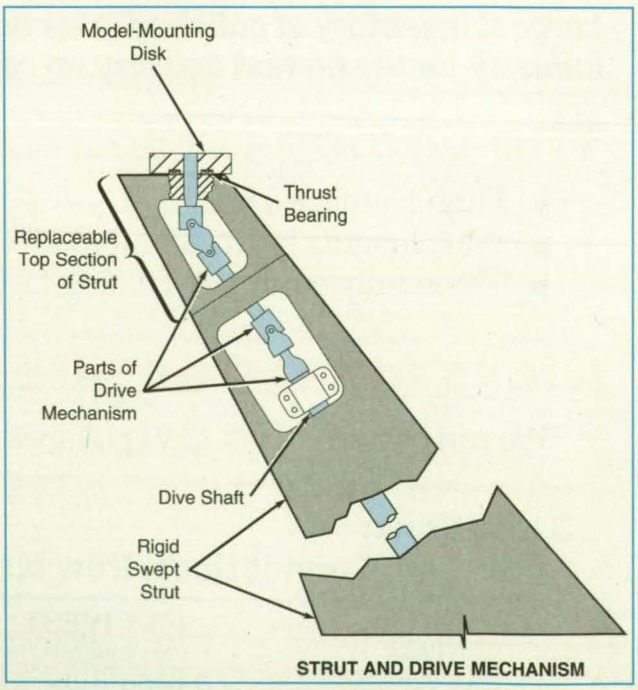
This work was done by Richard M. Wood of **Langley Research Center** *and Eddie D. Ford of Lockheed Engineering & Sciences Co. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14758

The **Model Is Mounted** on the disk, which is rotated to the desired azimuth angle

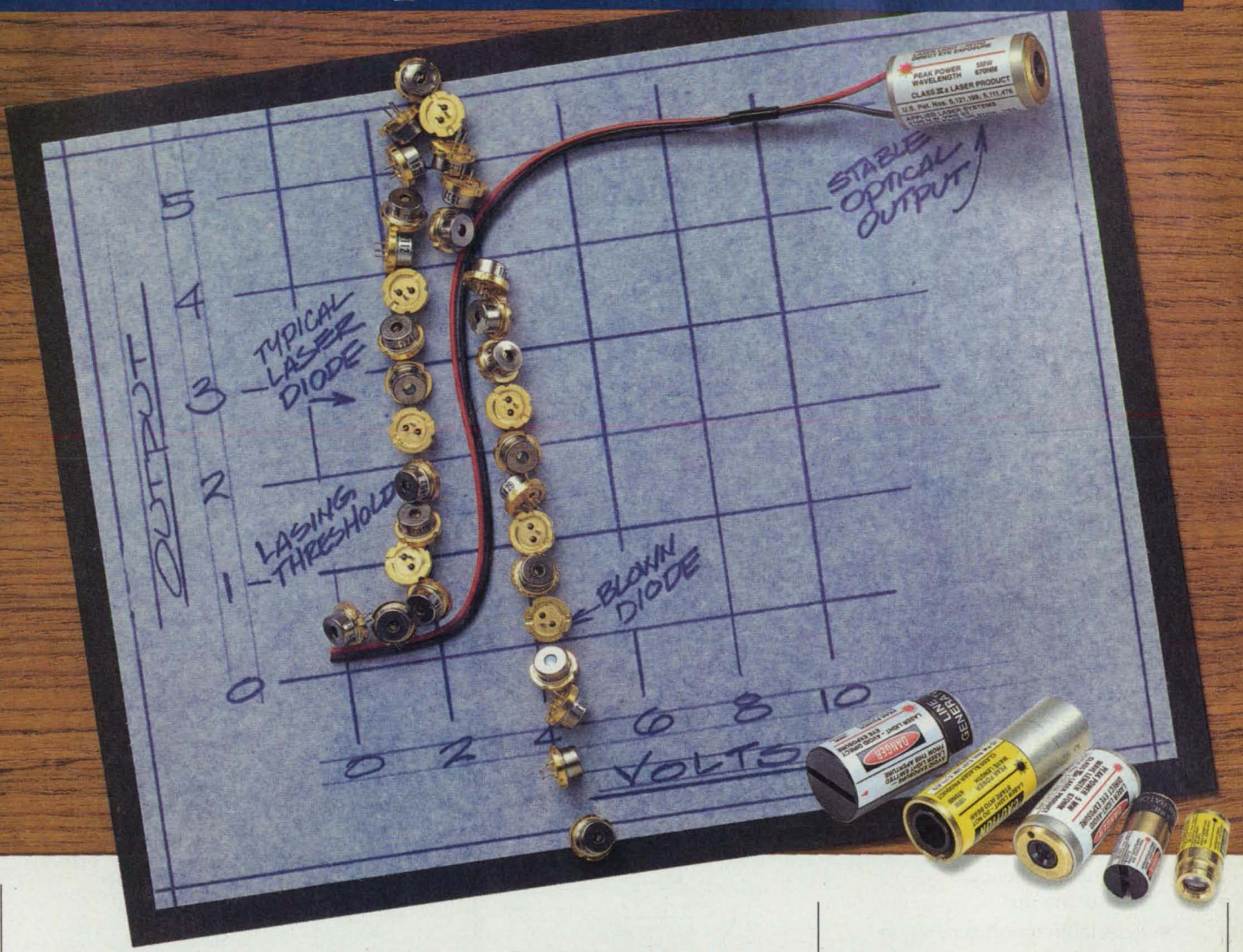


DETAIL OF THRUST BEARING AND DISK



STRUT AND DRIVE MECHANISM

What Goes Up, Usually Comes Down...



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Machinery

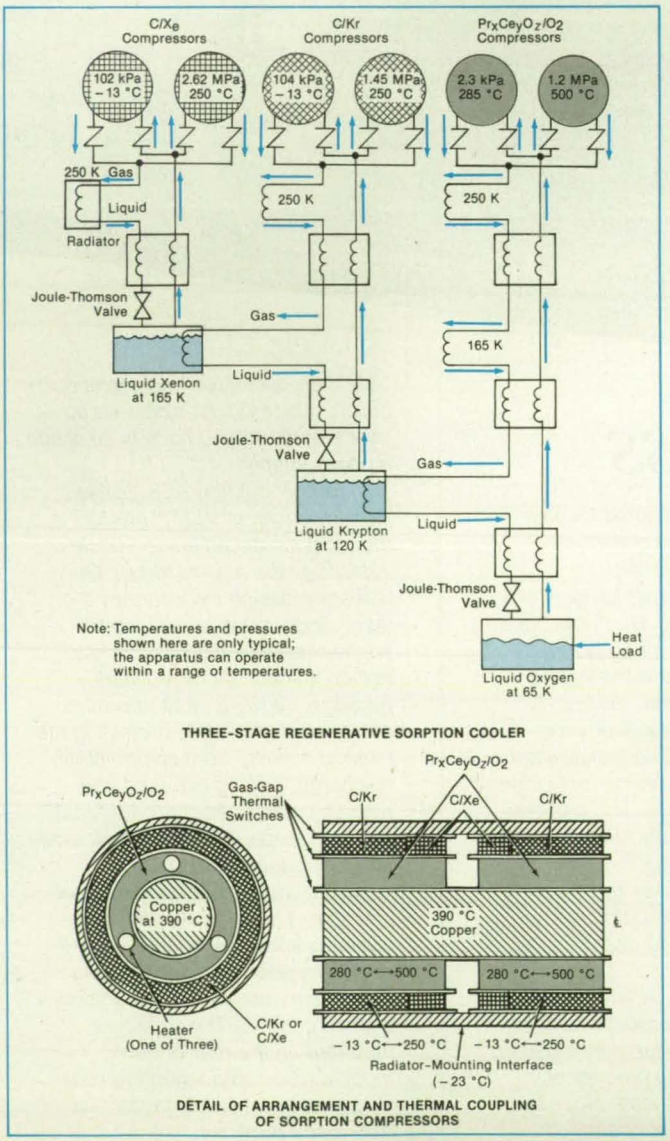
Three-Stage Regenerative Sorption Cooler Reaches 65 K

Efficiency is comparable to that of a Stirling-cycle cooler.

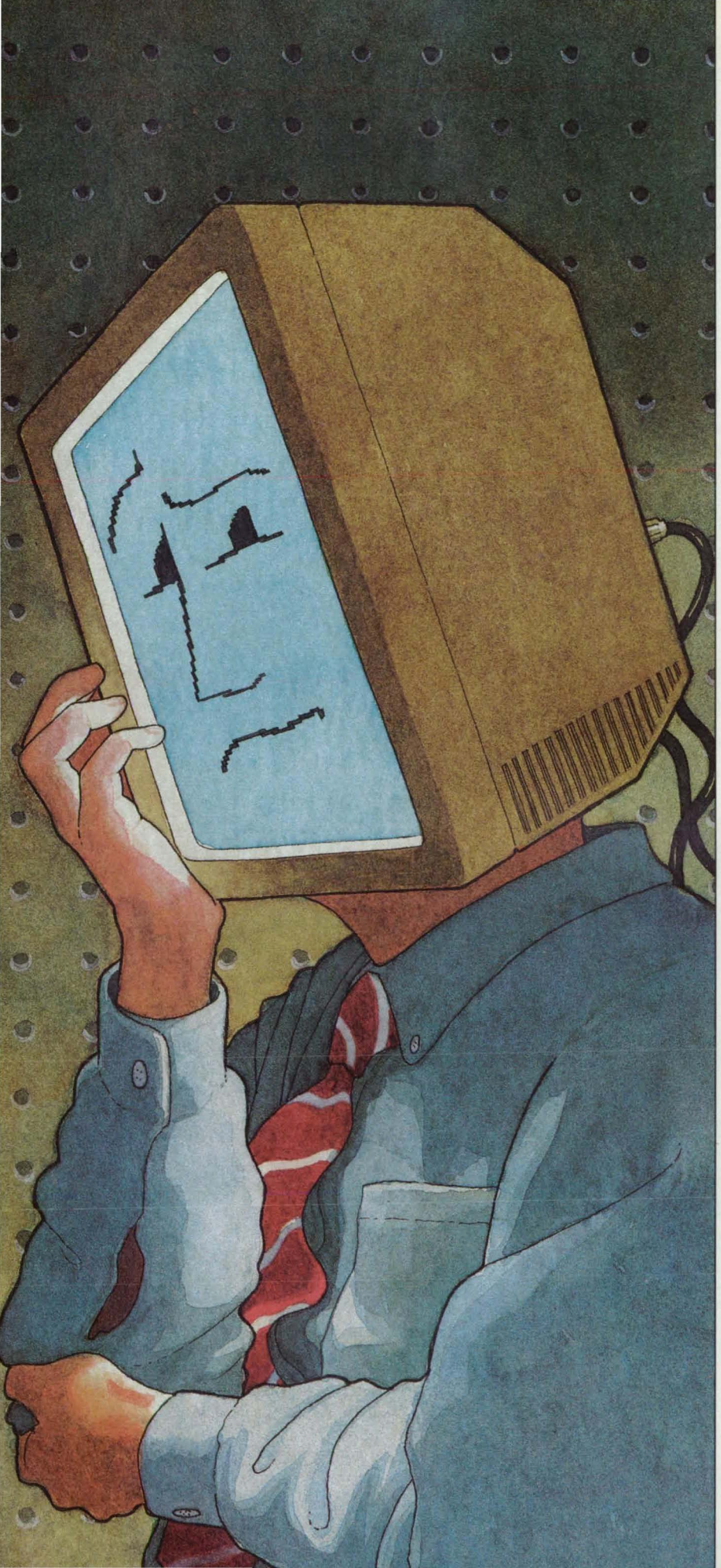
NASA's Jet Propulsion Laboratory, Pasadena, California

A three-stage regenerative sorption cooler provides 0.5 to 1.0W of third-stage cooling at temperatures from 65 to 90 K while consuming about 60 W of input power. If the first- and second-stage sorption compressors are made oversize, it can also provide additional cooling at 165 to 190 K and 120 to 140 K, respectively.

The power efficiency of this sorption cooler is comparable to that of a mechanical Stirling-cycle cooler and except for some check valves, this cooler includes no precise, wearing moving parts. Consequently, it produces no measurable vibration and is expected to last much longer in operation — possibly more than 10 years. The present cooler also represents an improvement over the two-stage sorption cooler described in "Regenerative Sorption Refrigerator" (NPO-17630), *NASA Tech Briefs*, Vol. 15, No. 3 (March 1991), page 51. That refrigerator was not as efficient as a Stirling-cycle cooler. Furthermore, it included a thermoelectric device (represented as a radiator in the illustration in the noted article) that provided 1.5 W of cooling at 200 K, and its sorption compressors operated at temperatures and



This **Three-Stage Regenerative Sorption Cooler** produces no measurable vibration, is highly reliable, and exhibits efficiency comparable to that of a less-reliable mechanical Stirling-cycle cooler.



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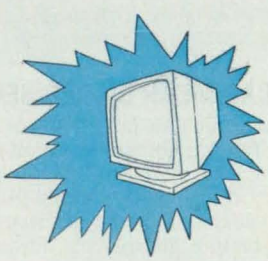

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pressures higher than those of the present cooler, with consequent adverse effects on reliability and lifetime.

The three-stage regenerative sorption cooler (see figure) includes two C/Xe and two C/Kr physisorption compressors and two $Pr_xCe_yO_z/O_2$ chemisorption compressors arranged concentrically and axially in two sets, with radial and axial thermal coupling controlled by gas-gap heat switches. The switches are activated to transfer heat as required to effect the two-phase operating cycle. These compressors supply flows of liquid Xe, Kr, and O_2 through Joule-Thomson expansion valves to provide the cooling fluids at the three stages of refrigeration.

At the time represented in the figure, the $Pr_xCe_yO_z$ compressor unit on the left is at its peak temperature and pressure of 500 °C and 11.8 atm (1.2 MPa), and the $Pr_xCe_yO_z$ compressor on the right is at its minimum temperature and pressure of 285 °C and 0.023 atm (2.3 kPa). The gas-gap heat switch between the $Pr_xCe_yO_z$ units and the central copper rod is then activated by adding small amounts of gas (e.g., helium) at about 10 torr (about 1.3 kPa) pressure. Heat from the left $Pr_xCe_yO_z$ unit then passes through the central copper rod over to the right $Pr_xCe_yO_z$ unit. The temperature of the two $Pr_xCe_yO_z$ compressors eventually equalizes at about 390 °C.

Next, the heat switch between the left $Pr_xCe_yO_z$ and concentrically located C/Kr and C/Xe compressors is filled, and the $Pr_xCe_yO_z$ compressor continues to cool down to 285 °C, passing its remaining heat to the C/Kr and C/Xe compressors. The C/Kr and C/Xe compressors thus heat up to about 250 °C and liberate gas and pressurize to about 14.3 atm (1.45 MPa) and 25.9 atm (2.62 MPa), respectively. After cooling, the left $Pr_xCe_yO_z$ reabsorbs oxygen at low pressure; e.g., 0.023 atm (2.3 kPa) at 285 °C.

Meanwhile, a set of three heaters heats up the right $Pr_xCe_yO_z$ compressor from 390 to 500 °C, wherein oxygen is chemically liberated from the $Pr_xCe_yO_z$ at high pressure; e.g., 11 atm (1.1 MPa). The right C/Kr and C/Xe compressors pass their heat through the outer gas-gap heat switch to a radiator at –13 °C. When cooled to about –13 °C, the C/Kr compressor adsorbs Kr gas at about 1.03 atm (104 kPa), and the C/Xe compressor adsorbs Xe at about 1.01 atm (102 kPa).

By alternately filling and evacuating the gas-gap heat switches and turning the heaters in the $Pr_xCe_yO_z$ units on and off at the appropriate times, each of the compressors can be thermally cycled, thereby producing the pressures and flows required by the Joule-Thomson refrigeration loops.

This work was done by Steven Bard and Jack A. Jones of Caltech for ***NASA's Jet Propulsion Laboratory****. For further information,* ***write in 31*** *on the TSP Request Card.*

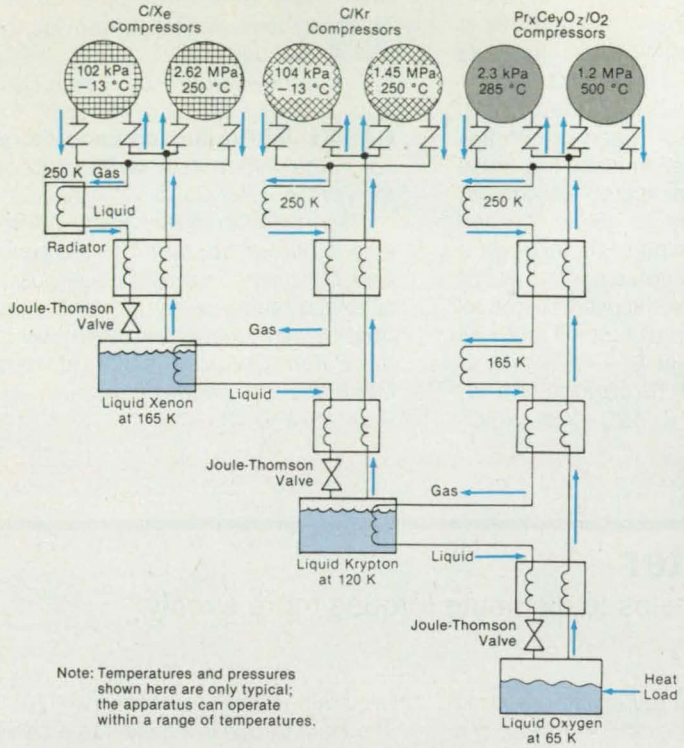
This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18366.

Simpler Three-Stage Regenerative Sorption Cooler

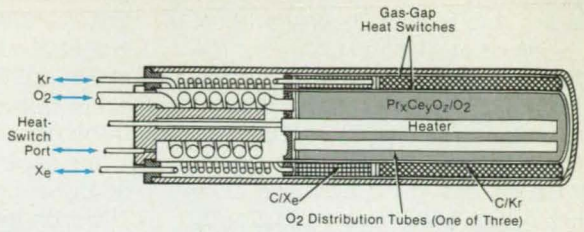
Some power efficiency can be traded for some simplification.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simpler version of the three-stage regenerative sorption cooler described in the preceding article has also been described. With the exception that it effects less regeneration



THREE-STAGE REGENERATIVE SORPTION COOLER



DETAIL OF ARRANGEMENT AND THERMAL COUPLING OF SORPTION COMPRESSORS

This **Three-Stage Regenerative Sorption Cooler** is a simpler version of the one described in the preceding article. In exchange for simplification, it requires about 1 ½ times the input power of the more-complicated version.

(and, therefore requires a little more power), this version offers all the advantages of the more-complicated version. Thus, it offers an additional engineering option to trade away some power efficiency to gain some simplicity (and the reliability that accompanies simplicity). This version requires about 88 W of input power to provide 1 W of cooling at 65 K.

The simpler apparatus operates on the same cooling cycle as that of the more-complicated version. As before, C/Xe and C/Kr sorption compressors operate on waste heat from the $Pr_xCe_yO_z/O_2$ sorption compressor, but the heating, plumbing, and thermal-coupling configurations are simpler (see figure).

At the beginning of a typical operating cycle, the central heater heats the

$Pr_xCe_yO_z$ unit from 280 to 500 °C, causing it to liberate O_2 chemically at a pressure of 11 atm (1.1 MPa). The gas-gap heat switch between the $Pr_xCe_yO_z$ and C/Kr units is then closed by introducing a small amount of gas, allowing heat to pass from the $Pr_xCe_yO_z$ unit to the C/Kr and C/Xe units in such a way that the $Pr_xCe_yO_z$ cools from 500 to 285 °C while the C/Kr and C/Xe units are heated from about –13 to 250 °C

At 285 °C, the $Pr_xCe_yO_z$ reabsorbs O_2 at a pressure of 0.023 atm (2.3 kPa), while the C/Kr liberates krypton at 14.3 atm (1.45 MPa) and the C/Xe liberates xenon at 25.9 atm (2.62 MPa). Next, the outer gas-gap heat switch is closed, allowing heat to pass from the C/Kr and C/Xe units to a radiator at about –13 °C. When cooled to about –13 °C, the C/Kr reabsorbs Kr at about 1.03 atm (104 kPa) and the C/Xe reabsorbs Xe at 1.01 atm (102 kPa).

The flows produced by the sorption compressors are used in Joule-Thomson refrigeration loops like those of the more-complicated apparatus. The high-pressure Xe gas is liquefied at 250 K and expanded through a Joule-Thomson valve to 165 K, at which temperature it is used to precool further the high-pressure Kr that has been precooled to 250 K. The Kr is then expanded through a Joule-Thomson valve to 120 K, at which temperature it is used to preliquefy the high-pressure oxygen. The oxygen is then expanded through a Joule-Thomson valve to 65 K to provide the final-stage cooling.

This work was done by Steven Bard and Jack A. Jones of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 42*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20].
Refer to NPO-18367.

Floating-Pinion Torque Splitter

Designed-in looseness at the right locations helps to distribute torques more evenly.

Lewis Research Center, Cleveland, Ohio

A gear-drive mechanism helps to apportion torques nearly equally along two parallel drive paths from an input bevel gear to an output bull gear. A mechanism of this type could be used, for example, as part of a redundant drive train between the engine and the rotor of a helicopter. The principal advantage of this torque-splitting mechanism is that it weighs less than do comparably rated prior torque-splitting mechanisms.

The input torque is supplied to a bevel gear (see figure) from a bevel pinion (not shown) connected to the engine or other source. Overall, the torque is transmitted

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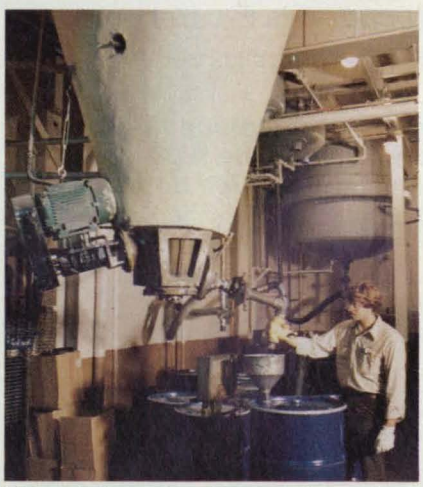

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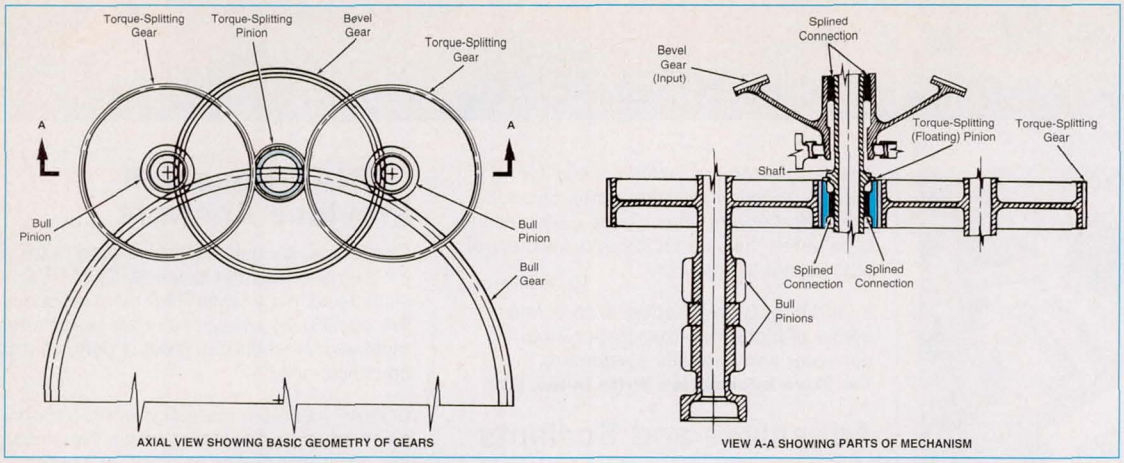


Splined Connections permit small angular excursions of a shaft, the bevel gear on its upper end, and the torque-splitting pinion on its lower end. These small excursions are essential for equalization of torques in the presence of machining tolerances and other geometric imperfections of the drive train.

from the bevel gear through a torque-splitting pinion to two torque-splitting gears, then from the two torque-splitting gears through the associated two bull pinions to the bull gear, then to the output shaft. The purpose of the torque-splitting feature is to distribute the loads as nearly equally as possible to all gear teeth in the two parallel load paths to keep the load on each tooth as nearly equal as possible, thereby prolonging the life of the gear train.

In a redundant drive mechanism of the same basic configuration but without explicit provision for torque splitting, the slightest deviation from precision in machining could cause the entire load to be transmitted along one of the two paths while the gear and pinion in the other path rotate freely. To provide explicitly for torque splitting in the presence of manufacturing tolerances, elastic deformations, and other deviations from the nominal precise gearing geometry, it is necessary to incorporate a low-spring rate member at one or more critical locations in the mechanism.

In this mechanism, the resultant load on the torque-splitting pinion is zero when the torque is identical on the left and right members. If there is a difference in torque, the resultant load will displace the torque-splitting pinion until the loads are again in balance, thereby ensuring equal loads in each path.

This work was done by Harold W. Melles of United Technologies Corp. for **Lewis Research Center**. *For further information,* ***write in 100*** *on the TSP Request Card.*
LEW-15073

Robotic Processing of Rocket-Engine Nozzles

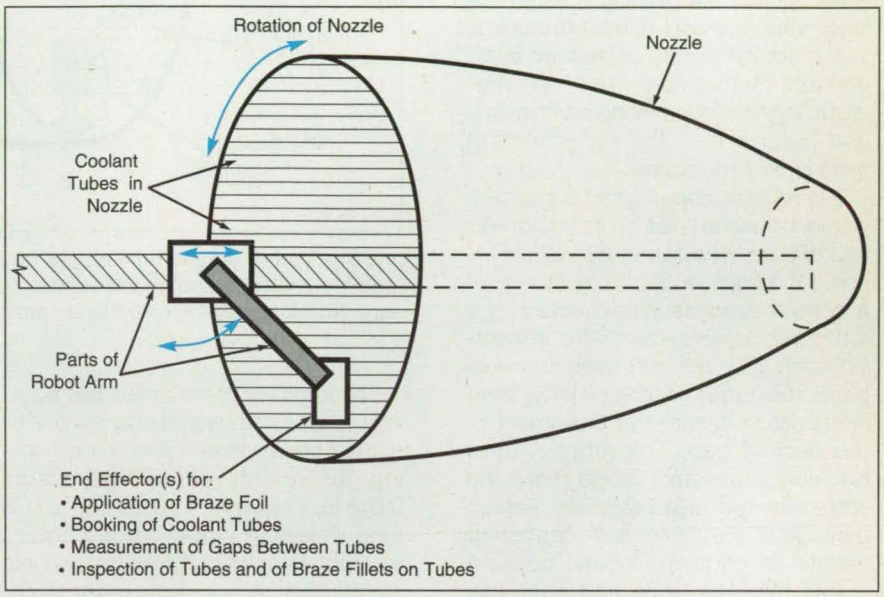
Advantages will include reduction of processing time and increase in consistency of results.

Marshall Space Flight Center, Alabama

An automated manufacturing cell that will contain a computer-controlled robotic processing system is being developed to implement some important related steps in the fabrication of rocket-engine nozzles. The robotic processing system will perform several tedious and repetitive fabrication, measurement, adjustment, and inspection processes and subprocesses that are now performed manually. The manual versions of these processing steps are not only labor-intensive and time consuming but also involve considerable subjectivity of judgment, inconsistency of results, and difficulty in acquisition of archival process data.

The automated manufacturing cell will offer the advantages of reduced processing time, greater consistency, excellent collection of data, objective inspections, greater productivity, and simplified fixturing. The computer-controlled robotic processing system will also afford flexibility: by making suitable changes in hardware and software, it will be possible to modify the process and subprocesses. This flexibility should also make the work cell adaptable to fabrication of heat exchangers and other items structured similarly to rocket nozzles.

The manufacturing cell will contain a standard nozzle dolly that will be modified to rotate the nozzle under computer control. Several of the processes and subprocesses will be performed with the nozzle mounted in the same position on the dolly. A robotic arm with two degrees of freedom will position an end effector (see figure). As the various processes and subprocesses are performed, the robotic arm will be fitted with various end effectors, each designed for a specific subprocess. The end effectors will be removed and installed either manually or else automatically by use of a robotic quick-change mechanism. The control software will be written in modules, all of which will be loaded into the computer. Each module will be capable of running independently and will control a particular process or subprocess. To supplement the computer-controlled collection of process data, a videotape recorder can be used to monitor the process and provide a visual record of the work performed.



The **Nozzle (or Other Workpiece) in Process** will be rotated while a two-degree-of-freedom robot arm positions an end effector.

Processing steps that have been selected for automation include the application of brazing foil, inspection of gaps between coolant tubes, booking of coolant tubes (see accompanying article), application of brazing alloy paste, and inspection of coolant tubes and of braze fillets on coolant tubes. Several preliminary proof-of-concept experiments have shown that these steps can be implemented in manners that are similar enough to enable integration of them into the processing routine of the automated manufacturing cell.

This work was done by Jeffrey L. Gilbert, John E. Maslakowski, David A. Gutow, and David C. Deily of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available. MFS-29927*

Robotic Booking of Coolant Tubes

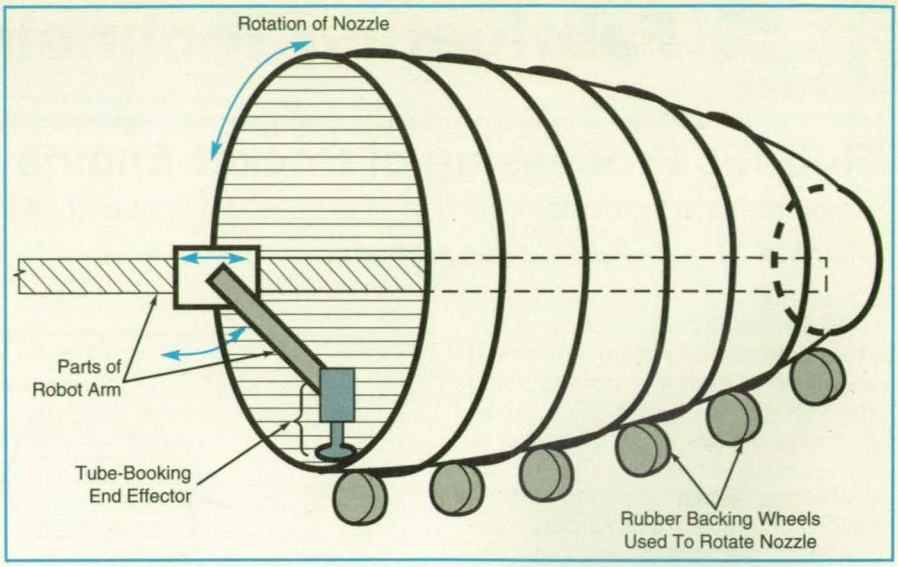
Advantages would include complete brazeable area and elimination of damage.

Marshall Space Flight Center, Alabama

A robotic tube-booking subsystem has been proposed for use in the automated manufacturing cell described in the preceding article, "Robotic Processing of Rocket-Engine Nozzles" (MFS-29927). As used here, "booking" means deformation of the tubes and adjustment of their positions to obtain the desired gaps between them.

In the case of the nozzle of the Space Shuttle Main Engine, to which the tube-booking system would be applied initially, the gaps between the coolant tubes must be 0.003 in. (0.076 mm) or less to ensure brazeability. Where the gaps are larger, the tubes must be booked to this specification without damaging them. At present, booking is done manually by use of a ball-peen hammer and polytetrafluoroethylene sheet. Manual ball peening is extremely labor-intensive and difficult to control; tubes are frequently dented or overbooked. Furthermore, there are variations in technique among technicians, and judgment of the reductions in gaps is very subjective.

The robotic tube-booking subsystem would include an electric or pneumatic end effector (see figure) that would inspect the gaps under the guidance of a control processor connected to a robotic vision subsystem. After inspecting each gap, the end effector would book the tubes in the vicinity, then reinspect to ensure the attainment of the desired gap. The robotic tube-booking subsystem would make the entire tube-gap area brazeable, without damage to the tubes, with consistent results. In addition, robotic booking would take less time and cost less than manual booking does.



Coolant Tubes Would Be Booked (that is, deformed) and inspected robotically by a specially designed end effector under computer control with dedicated application software. No system that can do this is commercially available now.

The feasibility of the pneumatic booking process has been demonstrated by manual operation of a pneumatic booking gun, which reduced gaps from 0.016 in. (0.41 mm) to 0.003 in. (0.076 mm) or less. It would be desirable to incorporate noise-damping features into a production version of the robotic tube-booking subsystem.

This work was done by Garret E. Wagner, David A. Gutow, Jeffrey L. Gilbert, and David C. Deily of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29925

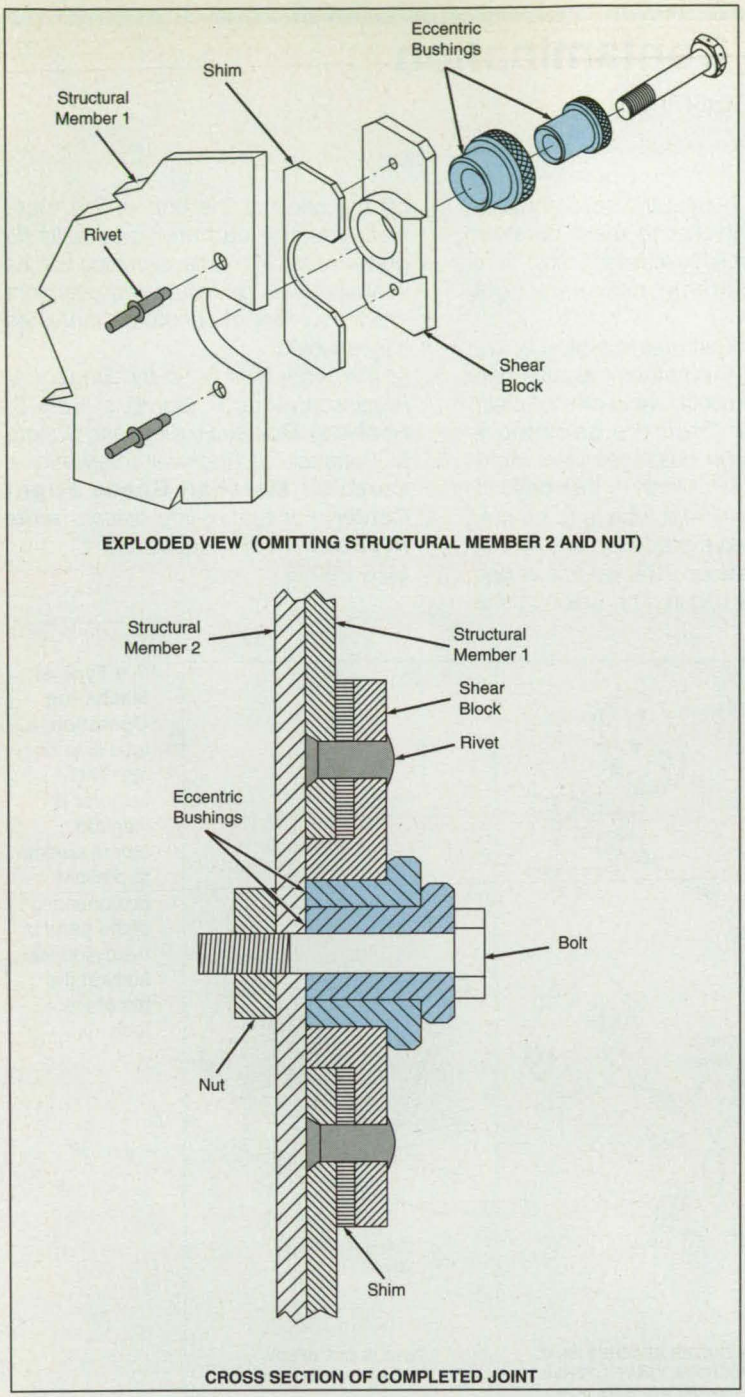
Bolted Structural Joint Sustains Reversing Shear Load

Eccentric bushings accommodate tolerances, yet provide a snug fit.

Marshall Space Flight Center, Alabama

The figure illustrates a bolted structural joint that satisfies competing requirements to accommodate tolerances yet fit snugly to sustain reversing shear loads. One technique used heretofore to accommodate tolerances between two structural members has been to drill oversize holes, then bolt the members together with washers covering the holes; but such joints, with their loose fits, cannot sustain high reversing shear loads. Alternatively, matched holes could be marked and drilled in both structural members at assembly to obtain the tight fit needed to sustain reversing shear loads, but this technique is not suitable for assembly of the structure in the field.

The present bolted joint includes a shear block that is riveted to one of the structural members. This shear block contains an oversize hole, which accommodates the tolerances on the centers of the boltholes in both structural members. Two eccentric bushings that fit precisely with each other, with the hole in the shear block, and with the bolt provide the snug fit needed to sustain reversing shear loads. The bushings can be turned, by use of knurled flanges, to align the bolt with the bolthole in the other structural member; this latter bolthole fits the



Inner and Outer Eccentric Bushings fit in a shear block. Frictional force generated by bolt tension prevents rotation of the bushings after assembly.

bolt precisely.

When the bolt is tightened, the resulting friction between the flanges of the eccentric bushings and between the shear plate and the flange of the outer eccentric bushing is more than enough to prevent the eccentric bushings from turning when reversing shear loads generate turning moments. In tests, a bolt prestressed to 18 kpsi (124 MPa) locked the bushings against rotation at an applied shear load of 3,800 lb (16.9 kN).

This work was done by J. B. Mott and D. Medley of Teledyne Brown Engineering for **Marshall Space Flight Center**. *For further information,* ***write in 29*** *on the TSP Request Card.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the Teledyne Industry. Inquiries concerning rights for its commercial use should be addressed to

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Refer to MFS-28744, volume and number of this NASA Tech Briefs *issue, and the page number.*

Balloon Catheter Prevents Contamination

An inflatable device seals out debris from machining.

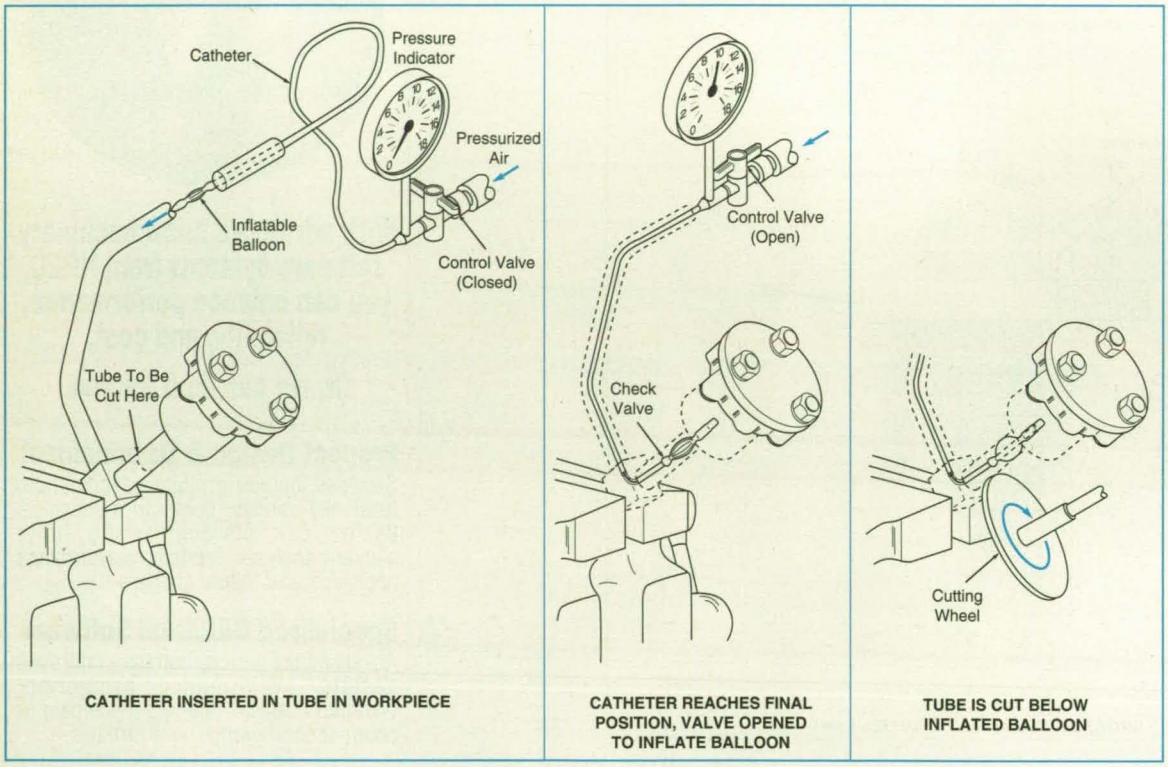
Marshall Space Flight Center, Alabama

A balloon catheter similar to that used in such medical procedures as angioplasty and heart surgery protects small orifices against contamination and blockage by chips generated in machining operations. The catheter includes a small, inflatable balloon at the end of a thin, flexible tube. Although essentially the same as a pulmonary-artery catheter, it contains additional features that adapt it to anticontamination service. For example, the balloon is larger to fit the wider channel that it must block; it is made of polyurethane (rather than latex), which does not fragment if it bursts; the balloon material is made thicker to resist abrasion better; and a kink-resistant axial wire helps the catheter negotiate tight bends.

The figure illustrates a typical application. First, the catheter is attached to the closed control valve of a pressurized-air line. Then the catheter is pushed through passages in a workpiece until the balloon is just beyond the position where a tube is to be cut. The control valve is opened and the air inflates the balloon. The valve is closed and cutting is begun. The balloon seals off the parts at the end of the tube. Because the catheter can hold its pressure for 2 to 3 days, cutting can be interrupted — perhaps even overnight — without fear of contamination when it is resumed.

This work was done by Gregory A. Higginson, Marc R. Bouffard, Beth S. Hoehicke, Bradley D. King, and Sandra L. Peterson of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 33*** *on the TSP Request Card.*

MFS-29908



In a **Typical Machining Operation**, a tube is to be cut. The catheter is inserted before cutting to prevent contamination of the parts in the cylindrical body at the top of the tube.

Preventing Clogging in a Vacuum Plasma Spray Gun

Modification of powder-injection ports enables lengthy, high-temperature deposition operations.

Marshall Space Flight Center, Alabama

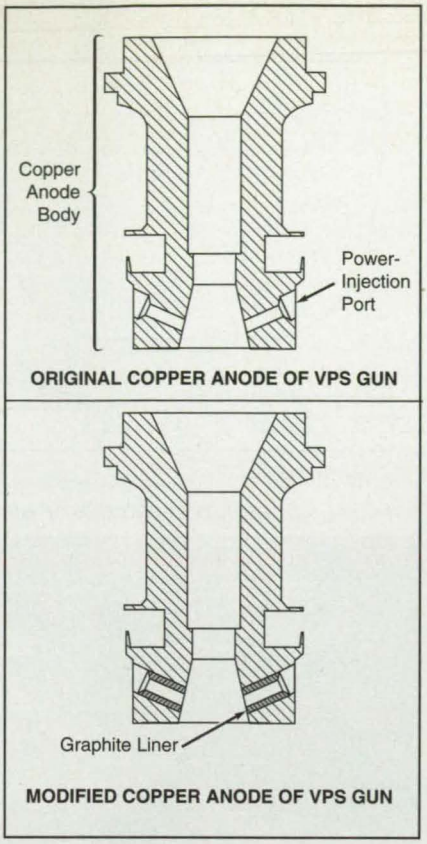
Graphite inserts prevent clogging of ports through which copper powder is injected into a vacuum plasma spray (VPS) gun. The graphite liners thus eliminate the need to spend production time refurbishing the VPS gun, thereby reducing the cost of production and increasing productivity.

In the VPS process, metal or ceramic powder to be deposited is injected into a plasma flame, which is created by the ionization of gases by a dc arc. This flame melts and accelerates the powder toward a substrate on which the powder is to be deposited. The plasma gun includes a tungsten cathode and a water-cooled copper anode, into which the powder-injection

ports have been drilled (see top part of figure). The VPS gun in question is being considered for use in depositing a copper alloy to form combustion-chamber liners thicker than 0.1 in. (0.25 cm). Deposition to such a thickness necessitates operation of the VPS gun at high temperature for several hours, during which powder builds up until it clogs the powder-injection ports, causing premature termination of deposition.

The powder-injection ports were modified by drilling them out to a larger diameter to accommodate the graphite inserts (see bottom part of figure). Graphite was chosen for this application partly because it can be tailored to have high thermal conductivity and high hardness to reduce wear. More important, however, is that copper does not wet or stick to graphite because of surface-energy considerations. The powder-port-liner concept could also be applied to other material systems to be used for net-shape fabrication via VPS if these considerations are evaluated case by case.

This work was done by Phillip D. Krotz, Ronald L. Daniel, Jr., and William M. Davis of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 38*** *on the TSP Request Card. MFS-29938*



Graphite Inserts in the modified anode prevent clogging because copper does not wet or stick to graphite.

Wire-Guide Manipulator for Automated Welding

The wire guide can be moved in three dimensions.

Marshall Space Flight Center, Alabama

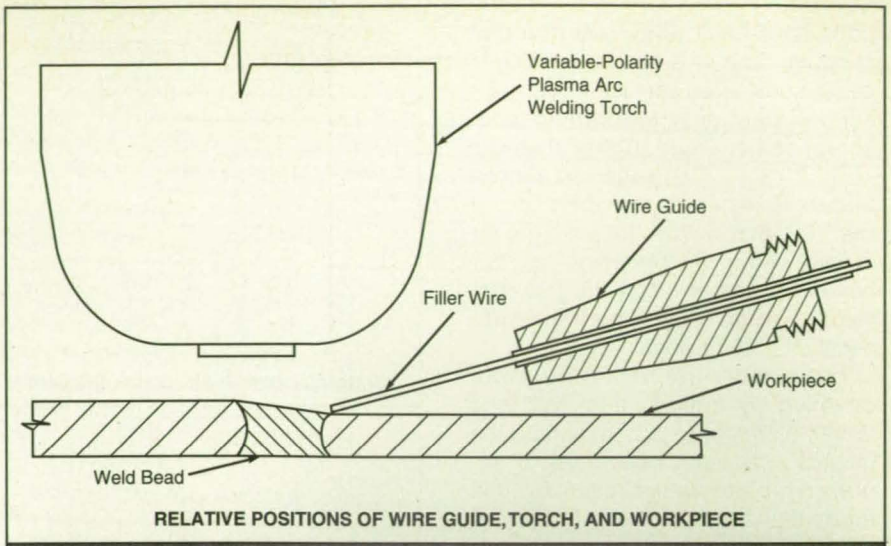
A compact motor drive positions a guide for welding filler wire. The drive is part of an automated wire feeder in a partly or fully automated welding system. The device is suitable for both variable-polarity plasma arc welding and gas/tungsten arc welding.

The drive unit moves the fille wire holder — and thus the tip of the wire at the weld bead — in three degrees of freedom:

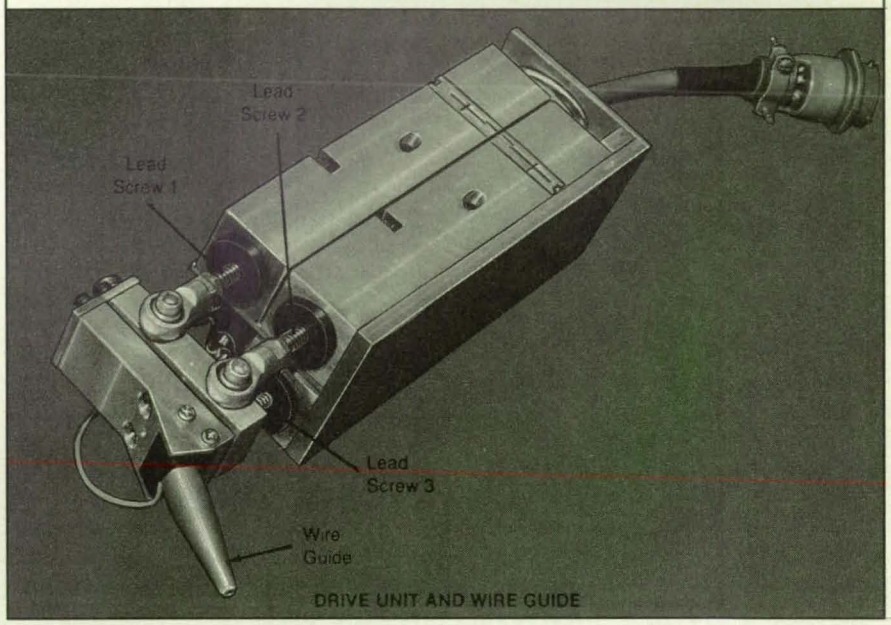
- Linear motion perpendicular to the direction of welding (perpendicular to the plane of the workpiece) over a range of 1 in. (2.54 cm),
- Transverse to the direction of welding (but in the plane of the workpiece) over a range of 0.5 in. (1.27 cm), and
- Rotation over a range of 30° in the plane perpendicular to the direction of welding.

To provide these three degrees of freedom in a small package, the design of the drive incorporates an unusual system of three parallel lead screws, attached to the filler-wire guide with pivoting rod-end joints (see figure). By suitable control of common and relative motions of the lead screws, the wire guide can be made to move as desired. For example, motion of all screws in the same direction at the same speed moves the holder perpendicular to the plane of the workpiece. Moving screws 1 and 2 opposite to screw 3 moves the holder transversely. Moving screws 2 and 3 opposite to screw 1 rotates the holder.

Each lead-screw mechanism includes



RELATIVE POSITIONS OF WIRE GUIDE, TORCH, AND WORKPIECE



DRIVE UNIT AND WIRE GUIDE

The **Drive Unit** contains three parallel subunits. The rotations of the lead screws in the three subunits are coordinated to obtain the desired motions in three degrees of freedom.

a motor of 22-mm diameter with an encoder and gearhead coupled directly to a drive sleeve and nut held by a single bearing. The nut drives the lead screw. An optical switch detects the arrival of the lead screw at the midpoint of its travel. The encoder measures the distance traveled from the midpoint and thereby provides a position-feedback signal to control circuitry. Motor control is complex because all three motors are used for each degree of freedom and their motions must, therefore, be coordinated.

The drive contains relatively few moving parts. It is contained in a monolithic housing. It includes a rigid coupling between each motor and its drive sleeve, plus only one bearing per lead screw. These features make it possible to keep the drive unit small. However, proper functioning necessitates accurately machined components; precise concentricity between all rotating components is critical. The drive exhibited no mechanical failures during many hours of testing in a simulated production environment.

This work was done by Tim Morris, Kevin White, Steve Gordon, Dave Emerich, Dave Richardson, Mike Faulkner, Dave Stafford, Kim McCutcheon, Ken Neal, and Pete Milly of Nichols Research Corp. for **Marshall Space Flight Center**. *For further information,* ***write in 34*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20].

Refer to MFS-26231.

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Optimal Preprocessing of GPS Data

The number of data is reduced without degrading the strength of the data.

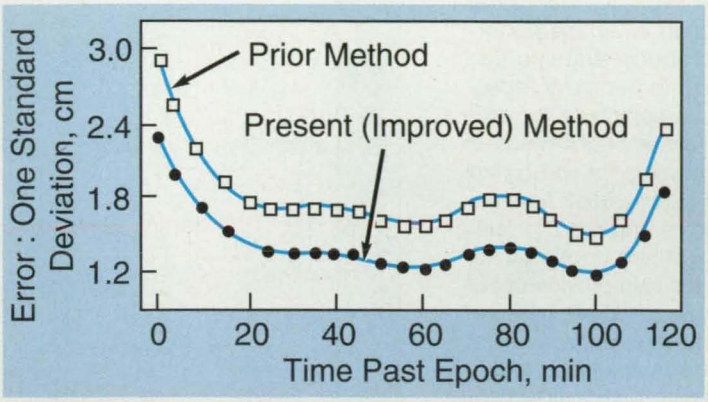
NASA's Jet Propulsion Laboratory, Pasadena, California

An improved technique for preprocessing data from a Global Positioning System (GPS) receiver reduces the processing time and the number of data that have to be stored. The technique is optimal in the sense that it maintains the strength of the data. It can also sometimes increase the ability to resolve ambiguities in the numbers of cycles of the received GPS carrier signals.

To give meaning to even a brief description of the improved preprocessing technique, it is necessary to describe some aspects of preprocessing and processing of GPS data. Preprocessing of GPS data involves combination of the four streams of GPS data, which are described below, into one stream of data. As used here, "strength" denotes a semiquantitative measure of the validity, utility, and/or precision of the data, and it increases with decreasing standard deviation of the data.

Preprocessing is applicable to data on the signals received from one GPS satellite. Each GPS satellite transmits at two frequencies: f_1 = 1.57542 GHz and f_2 = 1.2276 GHz. By use of (1) satellite-ephemeris data broadcast via at least four GPS satellites themselves plus (2) measured times of arrival of signals from these GPS satellites, the data-processing subsystem in a GPS receiver can compute the position of the receiver. The range (distance) between the receiver and each satellite transmitter is an essential component of GPS data.

A GPS receiver can acquire two types of precise data from the f_1 and f_2 signals from each satellite: these are the P-code pseudoranges and the phases of the f_1 and f_2 carrier signals.Except for contamination by clock errors, atmospheric delays, and instrumental delays, pseudorange is an absolute measure of the range between the transmitter and the receiver. The phase of a carrier signal is also a measure of range but differs from pseudorange in two respects: it is biased by an unknown integral number of cycles, and it is characterized by a data noise much lower than that of pseudorange. Hence, these two data types complement each other nicely, and together they provide information substantially stronger than does either by itself.



The **Error in Determination of Position** of a site that carries a GPS receiver is reduced by use of the improved data preprocessing technique.

It is common practice to combine measurements at the two frequencies to remove the ionospheric delays. This combination is performed independently, and thus suboptimally for pseudorange and carrier phase, leaving two streams of data to be used in the estimation process that follows. These two streams of data can be combined further to reduce the volume of data, but the preprocessing technique used heretofore for this purpose was again suboptimal in that it diminished the strength of the data.

The four streams of GPS data from one satellite are given by

$\Phi_1(t_i) = \rho(t_i) - \alpha_1\xi(t_i) + B_1$ with data noise σ_Φ

$\Phi_2(t_i) = \rho(t_i) - \alpha_2\xi(t_i) + B_2$ with data noise σ_Φ

$R_1(t_i) = \rho(t_i) + \alpha_1\xi(t_i)$ with data noise σ_R

$R_2(t_i) = \rho(t_i) + \alpha_2\xi(t_i)$ with data noise σ_R for i = 1, 2,... N, where t_i is the ith observation time, Φ is the measured phase of a carrier signal, R is a measured pseudorange, the subscripts 1 and 2 denote the two frequencies, $\rho(t_i)$ is the ionosphere-free pseudorange, $\xi(t_i)$ is a quantity proportional to the line-of-sight ionospheric electron content, B_1 and B_2 are carrier-phase biases (ambiguities in the numbers of cycles), which are unknown and constant over the whole span of the data,

$$\alpha_1 = f_2^2/(f_1^2 - f_2^2)$$

and

$$\alpha_2 = f_1^2/(f_1^2 - f_2^2).$$

The data noise is assumed to be white and of the same level in the f_1 and f_2 signals. This completes the necessary description of GPS data to be preprocessed and processed.

The improved preprocessing technique is based partly on elimination of B_1 and B_2 in the data-stream equations and introduction of a correlation between the Φ_1 and Φ_1. It is feasible to base the technique partly on these concepts because a common bias with a given uncertainty is equivalent to a fully correlated data noise of the same uncertainty. The resulting modified data-stream equations are written in a matrix•vector form that facilitates simplification, leading to a complicated but nevertheless closed-form equation that combines the four streams of data into an optimal, weighted-least-squares estimate of $\rho(t_i)$, plus an associated equation for the covariance of ρ; the form of the latter equation is identical to that of a stream of carrier-phase measurements with a constrained bias. The figure illustrates an example of the increase in precision afforded by use of the improved processing technique.

This work was done by Sien-Chong Wu and William G. Melbourne of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 6*** *on the TSP Request Card.*

NPO-18767

Frequency Analysis of Data on Telerobotic Tasks

Spectral signatures could lend insight into design and performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

Data on forces and torques measured in experiments with remote manipulators can be processed into spectral signatures via a special frequency-analysis procedure. The spectral signatures complement other measures used to evaluate performances of telerobotic systems and human operators. In particular, spectral signatures can contribute to verification of some assumptions made in designing manipulator arms and control subsystems and can be used as feedback by operators engaged in real-time monitoring of telerobotic tasks. Spectral signatures also provide useful indications of flows of power between manipulators and their environments: this is important in that it is highly desirable to minimize both task-execution times and the magnitudes of forces and torques employed in tasks, thus minimizing such flows of power.

The telerobotic experiments involve various tasks and subtasks in which the operator commands the remote manipulator to move a peg to a marked location on a board, tap the peg on the mark, move the peg to a hole in the board, insert the peg in the hole, release the peg, regrasp and extract the peg, return to and tap the mark with the peg, then move the peg to a final position. The start-and-stop motions in these subtasks give rise to sudden changes in torques and forces on the manipulator, so that traditional spectral analysis is almost useless in analyzing the resulting force and torque data. In the special frequency-analysis procedure, which was developed specifically for this application, segmentation algorithms are used to extract data on homogeneous subtasks from different experiments. By so doing, the algorithms synthesize artificial streams of data, such that all data in a given stream pertain to a given substask — for example, move, grasp, or insert.

The segmentation algorithms include a Viterbi-decoder algorithm based on an underlying hidden Markov model of the peg-in-hole task and its subtasks. A hidden Markov model is a mathematical model of a Markov process that cannot be observed directly. Each state of the Markov model is associated with a probability density that manifests itself in the experimental observations. In most cases, the probability densities overlap, and the problem of recognizing the sequence of states that generates a given sequence of measurement data involves the combination of information on probabilities of transitions between states with state-observation densities and with the specific sequence of observations. The figure presents an example of segmentation of force data by use of the hidden Markov model plus intervention by the operator to establish the intermediate "tap" states that correspond to the tapping substasks.

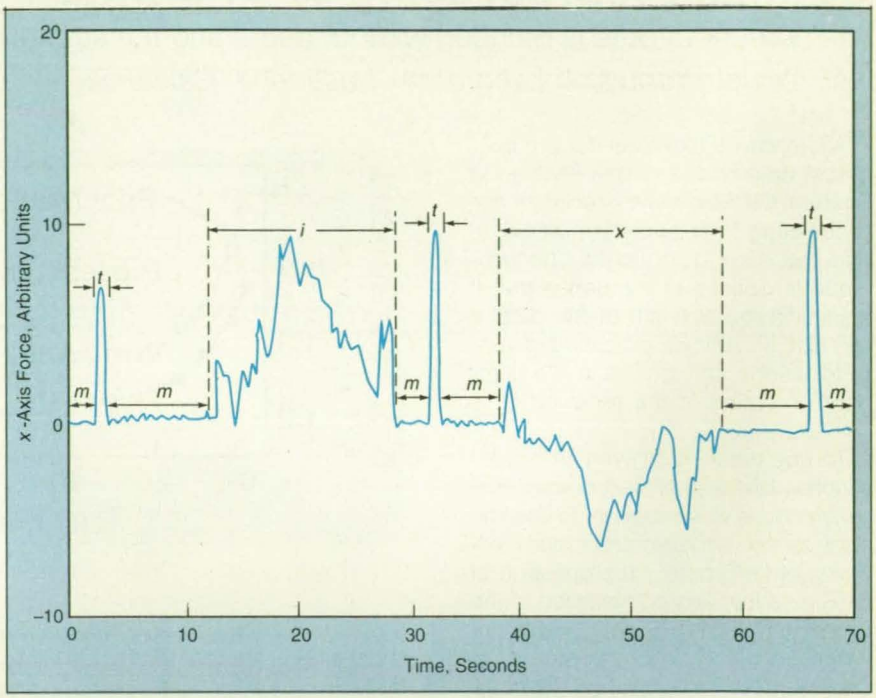


Figure 1. These **Force Data** from a peg-in-hole experiment have been segmented by use of the hidden Markov model. The letter symbols *i*, *m*, *t*, and *x* denote the "insert," "move," "tap," and "extract" Markov states, which correspond to subtasks of the same names.

Following segmentation, the data that pertain to the taps are eliminated, and the remaining data on each subtask are filtered by use of a Hanning window over time. Filtering is necessary to compress the data at the tails of the subtasks and reduce their effects on the spectra. The data on homogeneous tasks are then combined into a single file, and this file is processed with a fast Fourier transform to obtain the desired spectral signature (see Figure 2).

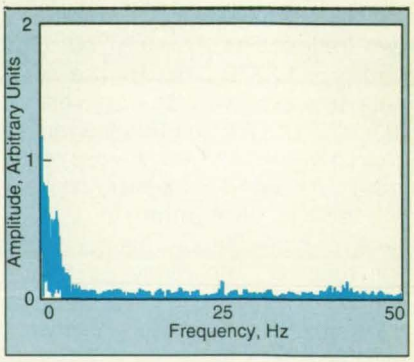


Figure 2. This **Frequency Spectrum** of force data for a complete peg-in-hole experiment was generated by the method described n the text.

This work was done by Paolo Fiorini and Antonio Giancaspro of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 12*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office– JPL [see page 24].
Refer to NPO-18805.

Continuous-Flow Gas-Phase Bioreactors

Separation of products from aqueous solutions would not be necessary.

NASA's Jet Propulsion Laboratory, Pasadena, California

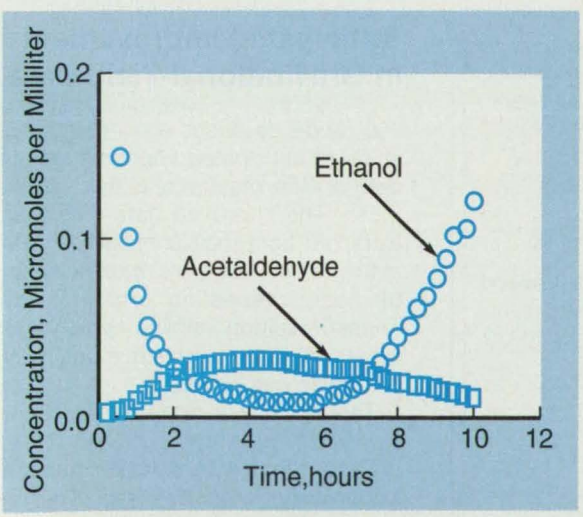
Continuous-flow gas-phase bioreactors have been proposed for biochemical, food-processing, and related industries. A reactor of this type would contain one or more selected enzymes that have been dehydrated or otherwise immobilized on a solid carrier (e.g., enzyme-coated carrier beads). Selected reactant gases would be fed into the reactor, wherein chemical reactions catalyzed by the enzyme(s) would yield product biochemicals.

This bioreactor concept is based on the discovery that enzymes do not necessarily have to be placed in the traditional aqueous environments to function as biocatalysts; enzymes at reduced hydrations have been shown to function either neat or suspended in organic solvents or supercritical fluids. This discovery has expanded the variety of reactions that can be considered for enzyme-based biocatalysts.

For those situations in which the reactants are gases or can be vaporized, gas-phase reactions in the presence of dehydrated enzymes are advantageous over reactions in aqueous solutions for several reasons. First, the dehydrated form of a typical enzyme can be more resistant to thermoinactivation than is the aqueous form: this enables the use of temperatures greater than those that could be used with aqueous solutions. Second, diffusivities in the gas phase are orders of magnitude larger than in water. Third, the concentrations of gaseous reactants can be increased directly by increasing the pressures in the reactors, circumventing problems of low solubility in aqueous phases. Fourth, the products of gas-phase reactions (including unconverted reactants) can be separated and recovered by facilitated fractional condensation with high purities, avoiding difficult and expensive separations from aqueous solutions.

In preparation for a series of experiments to demonstrate the feasibility of this bioreactor concept, alcohol oxidase (the enzyme) was immobilized on various solid supports. Then the biocatalysts thus prepared were exposed to reactant streams of ethanol vapor in air in the effort to oxidize the ethanol to acetaldehyde. The figure shows the concentrations of acetaldehyde and unconverted ethanol obtained in one of these experiments. Further development will be needed to overcome the short lifetime of the catalyst and the low percentage of conversion, both of which are evident in these plots.

This work was done by Donald L. Wise and Debra J. Trantolo of Northeastern University for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 41*** *on the TSP Request Card.*
NPO-18948



These **Concentrations of Acetaldehyde and Ethanol** were measured as a function of reaction time in an experimental continuous-flow gas-phase bioreactor.

Books & Reports

These reports, studies and handbooks are available from NASA Technical Support Packages (TSP's) when a Request Card is cited; other- wise they are available from NASA Technical Information Service.

PHYSICAL SCIENCES

GPS Measurements Show Subdaily Changes in Earth Rotation

A report presents an analysis of data from a 3-week worldwide Global Positioning System (GPS) tracking experiment that was conducted from January 22 through February 14, 1991. The focus of the analysis was upon detection and interpretation of subdaily variations in the rate of rotation of the Earth. These variations are interesting since they are caused by interactions between solid and fluid portions of the Earth and permit unique insights into Earth-system science. They are important as their neglect introduces significant systematic errors in space navigation.

This work was done by Stephen M. Lichten, Steven L. Marcus, and Jean O. Dickey of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Sub-Daily Resolution of Earth Rotation Variations With Global Positioning System Measurements,"* ***write in 61*** *on the TSP Request Card.*
NPO-18838

Dynamics of Two Ions in a Time-Varying Potential

A report summarizes a computer-simulation study of the motions of two ions trapped in a time-varying axisymmetric potential well. In practice, such a potential is created by applying suitably configured radiofrequency electric fields; for example, in a high-resolution trapped-ion atomic clock or frequency-standard apparatus. The two-trapped-ion problem has been studied because it is a paradigm of nonlinear dynamics, with implications not only for the behavior of larger numbers of trapped ions but also for applications as diverse as control systems and dynamics of fluids.

This work was done by Angelyn P. Williams and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Chaos and Dynamical Behavior of Two Ions Confined in RF Traps,"* ***write in 27*** *on the TSP Request Card.*
NPO-18684

Anticipated Improvements in Gravitational-Field Data

A report describes a computational study of anticipated improvements in data on the gravitational field of the Earth. The improved data would be extracted from measurements, by use of the Global Positioning System (GPS), of nearly repeating orbits of the Topex/Poseidon satellite (which was scheduled to be launched shortly after this article was written).

This work was done by William I. Bertiger, Jiun-tsong Wu, and Sien C. Wu of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the re-*

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Paper Categories

1. Lasers and Laser Systems **2.** Lenses and Optical Systems **3.** Fiber Optics Devices and Systems **4.** Electro-Optical Systems **5.** Infrared Technology **6.** Detectors, Cameras, and Imaging Devices **7.** Positioning and Motion Control Equipment **8.** Test and Measurement Equipment **9.** Design, Fabrication, and Manufacturing

Deadline For Submission

Paper abstracts must be submitted to the Program Chairman no later than April 29, 1994. They should be 1 to 1-1/2 pages long and MUST describe the technology's novelty and commercial potential (see abstract format).

Mail or fax abstracts to:

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Program Chairman
LaserTech '94
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*port, "Gravity Field Improvement Using GPS Data From Topex/Poseidon: A Covariance Analysis," **write in 96** on the TSP Request Card. NPO-18333*

Heating and Positioning in a Microwave Cavity

Two reports describe theoretical and experimental studies of (a) microwave dielectrophoretic positioning of a spherical sample of lossy dielectric material in a microwave resonant cavity and (b) the heating of the positioned sphere by the electromagnetic field. These studies are parts of a continuing effort to develop techniques for containerless (more accurately, contactless) processing of materials in microgravity.

Previous studies in this series were described in "Microwave Dielectrophoretic Levitation in Microgravity" (NPO-18824), *NASA Tech Briefs*, Vol. 17, No. 10 (October 1993), page 120. The positioning principle of the present and previous studies involves exciting the appropriate resonant mode(s) of the microwave cavity to obtain the potential well of the dielectrophoretic force field, away from the wall of the microwave cavity, where the sample can be held stably. By manipulation of the excited mode(s), one could move the sample around the cavity, and by suitable phasing of degenerate modes, one could apply torque to rotate the sample.

This work was done by Henry W. Jackson, Martin B. Barmatz, and John L. Watkins of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain copies of the reports, "Applications of Improved Methods for Calculating Electromagnetic Properties of a Microwave Cavity Containing a Lossy Dielectric Sphere" and "Microwave Processing of Materials in Microgravity," **write in 80** on the TSP Request Card. NPO-18881*

MACHINERY

High-Temperature Rocket Engine

Two rocket engines that operate at a temperature of 2,500 K, as compared with 1,700 K for older engines of the same general type, are designed to provide thrust for station-keeping adjustments of geosynchronous satellites, for raising and lowering orbits, and for changing orbital planes. The engines may also be useful as the final propulsion stages of launch vehicles that will deliver small satellites to low orbits around the Earth. With further development, the engines could be used on planetary exploration missions for orbital maneuvers. The high-temperature technology of these engines may also be adaptable to gas-turbine combustors, ramjets, scramjets, and the hot components of many energy-conversion systems.

This work was done by Steven J. Schneider of **Lewis Research Center**, *Sanders D. Rosenberg of Gencorp Aerojet, and Melvin L. Chazen of TRW, Inc. To obtain a copy of the report, "High-Performance Rockets for Satellites: Aerojet AJ10-221, TRW Advanced DM-LAE," **write in 64** on the TSP Request Card. LEW-15774*

Integrated Booster-Rocket Propulsion Module

A report summarizes a study of a conceptual integrated booster propulsion module for use in launching a spacecraft. The substitution of the integrated propulsion modules for the multi-

ple engines of present booster rockets is intended to simplify ground operations and reduce costs. The conception of the integrated booster propulsion module was motivated by focusing on operational efficiency. According to the concept, many duplicate components and subsystems, with their many interfaces, would be integrated to make the module function as a single engine with a minimum number of components.

This work was done by Russell E. Rhodes and William J. Dickinson of **Kennedy Space Center** *and George S. Wong and Glen Waldrop of Rockwell International Corp. To obtain a copy of the report, "Fully Integrated Propulsion Module,"* ***write in 57*** *on the TSP Request Card.*
KSC-11601

Studies of Vibrations in Gearboxes

Three NASA technical memorandums summarize studies of vibrations in gearboxes. These studies are directed toward understanding and reducing the gearbox noise caused by coupling of vibrations from meshing gears, through gear shafts and their bearings, to the surfaces of gearbox housings. Practical systems in which the understanding and reduction of gearbox noise would be beneficial include helicopter, car, and truck transmissions; stationary geared systems; and gear-driven actuator systems.

This work was done by Fred K. Choy, Yeefeng F. Ruan, and Yu K. Tu of the University of Akron and James J. Zakrajsek, Fred B. Oswald, John J. Coy, and Dennis P. Townsend of **Lewis Research Center**. *For further information,* ***write in 65*** *on the TSP Request Card.*
LEW-15743

Life Sciences

More About Thin-Membrane Biosensor

A report presents additional information about the device described in "Thin-Membrane Sensor With Biochemical Switch" (MFS-26121), *NASA Tech Briefs*, Vol. 16, No. 1 (January 1992), page 79. To recapitulate: This device is a modular sensor that puts out an electrical signal indicative of a chemical or biological agent. The signal is produced as a membrane-crossing ion current triggered by the chemical reaction between the agent and a recognition

protein conjugated to a channel blocker. As such, this device is a prototype of a biosensor that could be useful in numerous laboratory, industrial, or field applications; for example, to detect bacterial toxins in food, to screen for disease-producing microorganisms, or to warn of toxins or pollutants in the air.

This work was done by George D. Case and Jennings F. Worley, III, of Resource Technologies Group, Inc., for **Marshall Space Flight Center**. *To obtain a copy of the report, "Thin Membrane Sensor With a Biochemical Switch,"* ***write in 32*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Resource Technology Group
400 Mississippi Street
Morgantown, West Virginia 26505

Refer to MFS-26211, volume and number of this NASA Tech Briefs issue, and the page number.

Bioregenerative Life-Support System for Long Missions

A collection of four reports proposes an integrated bioregenerative life-support system that would sustain tens of people who are isolated from the Earth's oxygen and sunlight. The system would be self-sufficient for a year or more; it would continue beyond that period with replenishment of its supplies. The system could be used in long-term spaceflights, space stations, such planet bases as those on the Earth's Moon or Mars, and submarine vehicles and installations.

This work was done by Hatice S. Cullingford of **Johnson Space Center**. *To obtain copies of the reports, "The Next Generation Life Support System for Air, Water, and Waste/Resource Processing and for Food Production," "Conceptual Design of a Piloted Mars Sprint Life Support System," "Bio-Isolation Analysis of Plants and Humans in a Piloted Mars Sprint," and "Method and Apparatus for Bio-Regenerative Life Support System,"* ***write in 26*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, [see page 20]. Refer to MSC-21629.

Mathematics and Information Services

Applications of Modern Systems Analysis

Four papers discuss applications of interdisciplinary methodologies that incorporate elaborate mathematical models and computer programs as paradigms of modern systems analysis. The unifying concept that underlies all four presentations is the need for ever more sophisticated methods of systems analysis to manage increasingly complex engineering and socioeconomic systems.

This work was done by Robert C. Wagner, John V. Biernacki, and Robert F. Bodi of Analytical Engineering Corp. and John E. Juhasz of Badwin Wallace University for **Lewis Research Center**. *To obtain copies of the papers,* ***write in 3*** *on the TSP Request Card. LEW-15752*

Electronic Systems

Performance of a Doppler-Corrected MDPSK Detector

A report presents a theoretical analysis of the effect of the rate of change of Doppler shift ("Doppler rate," for short) of a received multiple-differential-phase-shift-keyed (MDPSK) radio signal on the performance of a Doppler-corrected differential detector. In the particular detector, the phase of the received signal is corrected for the Doppler shift by use of a Doppler estimator that is designed to operate in the presence of a negligibly small Doppler rate. Thus, there arises a question of how the performance of the detector is degraded by a Doppler rate that is not negligibly small.

This work was done by Tien M. Nguyen, Thomas C. Jedrey, Sami Hinedi, and Martin J. Agan of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Effects of Doppler Rate on the Performance of a Doppler-Corrected Differential Decoder,"* ***write in 14*** *on the TSP Request Card.*
NPO-19191

New on the Market

A **rapid prototyping and tooling** technology introduced by 3D Systems, Valencia, CA, reduces the lead time on metal castings by 80 percent, according to the manufacturer. QuickCast™ permits the user to bypass the expensive and time-consuming machining of hard tooling traditionally required for wax patterns. Instead, plastic patterns are built directly on 3D Systems' stereolithography apparatus.
For More Information Write In No. 716

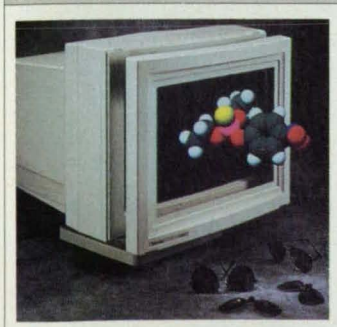
Pacific Cyber/Metrix Inc., Dublin, CA, has unveiled a **digital signal processing board** for real-time image processing. Mating three Texas Instruments TMS320C40 processors with a Motorola 68040 general-purpose processor, the DSP-48 extracts information from images acquired using visible-light cameras, tomographic equipment, radar, sonar, and infrared systems. The board aids the creation of autonomous vehicle controllers, object trackers, and robots that can act on image stimuli.
For More Information Write In No. 707

The Micro Slides Division of Anorad Corp., Hauppauge, NY, has introduced M & V **linear bearing guideways** for accurate guidance where roller bearings are inappropriate. The components feature a precision, Teflon bonded and ground guide rail to provide a highly reliable, wear-resistant surface that absorbs vibration and runs safely without additional lubrication. The guides' components are interchangeable with all standard crossed roller bearing mountings.
For More Information Write In No. 710

The Dimension® II **process controllers** from Research Inc., Minneapolis, MN, combine PID control with PLC capabilities in a single instrument. The units integrate single- or multi-loop control, setpoint programming, alarms, logic functions, and auxiliary sensor monitoring. Extensive limiting, scaling, and thermocouple linearization capabilities allow the user to set up input requirements and monitor processes according to specific applications.
For More Information Write In No. 721

An innovative **pump/compressor** introduced by EP Industries Inc., El Segundo, CA, produces up to 16 times the output of equally-sized units yet weighs one-fifth as much and costs two-thirds less to produce. The patented, valveless CEM (cylindrical energy module) has only five moving parts, which reduces friction, saves energy, and improves reliability. It can be scaled to virtually any size.
For More Information Write In No. 715

The Camad Company, Manhattan Beach, CA, has released QuickRUN™ software for creating **computerized motion control** programs without writing software. The PC-compatible package operates on Camad's 2300 series pulse and direction output and 2500 series ±10V analog output closed-loop motion controllers. QuickRUN offers built-in user interface screens and permits the user to select control parameters for each application.
For More Information Write In No. 720

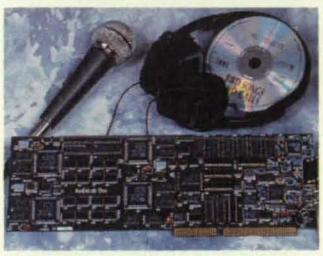


Tektronix Inc., Beaverton, OR, has unveiled two 19-inch color **stereoscopic displays** that are used with passive stereo glasses and feature integrated liquid crystal modulators. Incorporating patented pi-cell technology, the SGS19U and SGS19C offer higher contrast and more uniform brightness than previously available. Both displays can be used with a scan converter and cameras to create real-time, stereoscopic video.
For More Information Write In No. 718

New on the Market

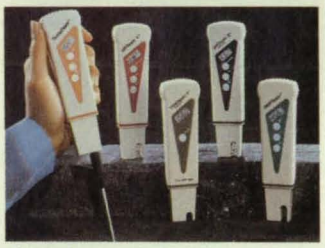
The *DSP Lab One*™ **digital signal processing board** from Standing Applications Laboratory, Kirkland, WA, runs more than 113 MIPS and combines real-time signal capture, analysis, and generation with high-resolution SVGA display in one 16-bit ISA slot. Each board features four TMS 320C51 digital signal processors and 16-bit stereo A/D and D/A converters running at up to 166K samples/sec.

For More Information Write In No. 712



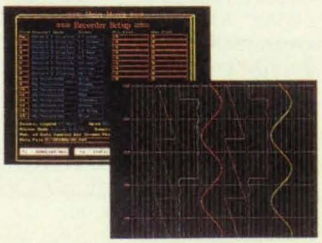
The *vmax/GP* scalable **data acquisition and control board** from Alta Technology, Sandy, UT, features a VME interface, six independent A/D and D/A channels, a 32-bit digital I/O port, 4 or 16 MB of shared memory, and a transputer controller for creation of multiprocessing environments. The A/D and D/A converters have 12-bit resolution and eliminate skew between sequential operations.

For More Information Write In No. 714



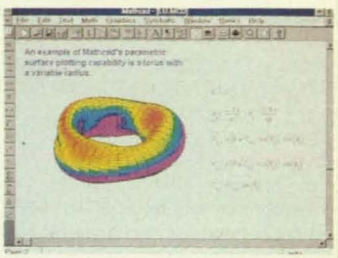
The industry's first microprocessor-based **pH test instruments** are available from Cole-Parmer Instrument Co., Niles, IL. The pHTestr1 features push-button calibration at 4.0, 7.0, or 10.0 pH, extended range pH measurement from -1.0 to +15.0 with ±0.2 accuracy, auto shutoff, and self-diagnostic error messages. The pHTestr2 includes automatic temperature compensation, multi-point calibration capability, and ±0.1 pH accuracy.

For More Information Write In No. 701



OMEGATREND™ **data acquisition software** from Omega Engineering Inc., Stamford, CT, offers a low-cost means to emulate high-speed strip-chart recorders. Data can be viewed from six channels and recorded from 16 simultaneously. Priced at $349, the software supports display rates up to 7000 samples per second.

For More Information Write In No. 705



Mathsoft Inc., Cambridge, MA, has released two new versions of its Mathcad **technical calculation software**. Mathcad 5.0, designed for mainstream users, offers enhancements such as equation and text editing, document preparation, improved graphics, automatic unit assignment, and an on-line tutorial. For more advanced users, the expandable Mathcad PLUS 5.0 incorporates all of 5.0's features as well as advanced numeric and symbolic calculations, differential equations, and matrix functions.

For More Information Write In No. 711

DeFelsko Corp., Ogdensburg, NY, has designed the first nondestructive, handheld **coating thickness gauge** that can measure concrete, wood, glass, and plastic coatings, as well as thin walls, delamination, and corrosion. The PosiTector 100 measures thicknesses to 0.0005" and features simple two-button operation and automatic calibration.

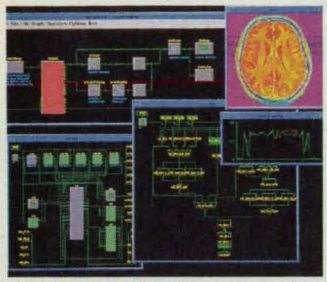
For More Information Write In No. 713

Micro Computer Specialists Inc., Vista, CA, has announced the ICB-486DX **single-board computer**, integrating the functionality of a standard motherboard and peripherals with a PC/104 expansion port and watchdog timer. Operating at up to 66 MHz, the AT-type plug-in board features a ZIF CPU socket and unique clock circuit that supports high-performance 486DX, 486DX2, and Intel Overdrive microprocessors.

For More Information Write In No. 717

New on the Market

UNICALC **scientific calculation software** for Windows, from Calchemy Software Inc., Ft. Collins, CO, allows users to calculate data having inconsistent units. Hundreds of common and esoteric units, including metric and SI, are supported and may be used in any combination. Priced at $79, the program provides feedback on dimensional errors while offering automatic dimensional analysis to reduce error.
For More Information Write In No. 703



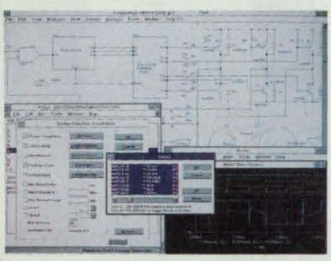
WitFlow **graphical programming software** from Datacube Inc., Danvers, MA, enables complex applications on the company's image processing systems without having to write extensive code. WitFlow represents imaging tasks visually as graphical models of processing elements and data paths. These models depict overall application data flow and control, generating C code that can be compiled and executed.
For More Information Write In No. 719

Spyglass Plot, a **scientific plotting and graphing tool** from Spyglass Inc., Savoy, IL, permits analysis of large datasets using interactive visualization techniques. Running on a UNIX or Macintosh workstation, Spyglass Plot generates line, double-Y, color scatter, and parametric plots. It can read many data formats including HDF, HDF Vset, spreadsheet, ASCII, and binary datasets.
For More Information Write In No. 709

Hitachi Denshi America Ltd., Woodbury, NY, has announced a **studio/field camera** that permits RGB digital video processing. The SK-2600 has a 62 dB signal-to-noise ratio and 900 lines of resolution. Auto set-up eliminates the need for diascopes and viewfinder picture-in-picture lets auxiliary video signals be positioned in four quadrants or reversed with the camera video.
For More Information Write In No. 704

The Power Wizard™, a digital, pocket-size **power probe** introduced by Synrad Inc., Bothell, WA, enables CO_2 and YAG measurements up to 200 W. The device has a built-in analog computer capable of sequential readings and requires an exposure time under two seconds. Priced at $400, the probe is powered by a long-life lithium battery, and features digital display, auto ranging, and auto shutoff.
For More Information Write In No. 702

The PLSyn **programmable logic synthesis** system from MicroSim Corp., Irvine, CA, is the first to enable design and simulation of a system with programmable logic, discrete digital, and analog parts on the same schematic. PLSyn simulates the entire design before and after the physical implementation has been selected, automatically compiling and simulating programmable logic.
For More Information Write In No. 708

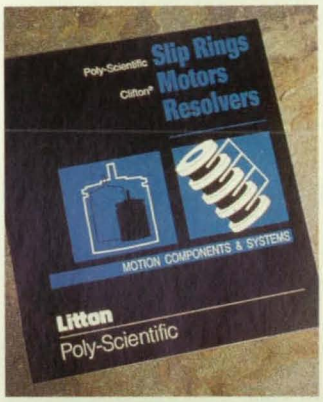


Sparcom Corp., Corvallis, OR, has released **mathematics software** for its HP 48GX calculator that features an advanced interface to aid beginners. Math•*Pro*™ includes over 1000 mathematics routines, analyses, equations, and references. The software comes programmed onto a plug-in expansion card and requires 5 KB of free calculator memory.
For More Information Write In No. 706

New Literature

A brochure from Litton Poly-Scientific, Blacksburg, VA, showcases its **motion control components**, including slip rings; brush and brushless DC, permanent-magnet, stepper, and DC torque motors; and multispeed, brushless, and brushless pancake synchros and resolvers. The company works with customers to design complete motion control systems offering savings in weight, accuracy, cost, and energy.

For More Information Write In No. 725

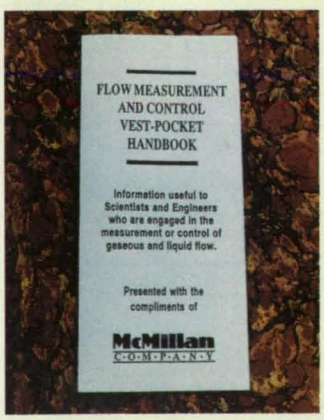


Innovative solutions to a wide range of **thermal management** problems are presented in a 16-page brochure from Lytron Inc., Woburn, MA. The company designs and manufactures standard and specialty fin-and-tube heat exchangers; high-performance, compact, lightweight plate-fin heat exchangers; cold plates and electronic card chassis; liquid-cooled plate-fin and solid aluminum thermal planes, and complete cooling systems.

For More Information Write In No. 726

A 24-page pocket handbook on **flow measurement and control** is available from McMillan Co., Georgetown, TX. The publication includes engineering tables on flow equivalents, viscosity rating systems, molecular weights and specific gravities of gases, and chemical resistance of gases, vapors, and liquids.

For More Information Write In No. 724



Entran Devices Inc., Fairfield, NJ, has released a catalog of miniature **pressure, force, and acceleration sensors**. Associated power supplies, meters, and amplifiers are included.

For More Information Write In No. 723

Apex Microtechnology Corp., Tucson, AZ, has published an expanded edition of its databook featuring **DC/DC convertors and power and high-voltage amplifiers**. New application notes address bridge mode and single supply operation of power operational amplifiers, stability, SOA and load lines, motor drives, driving capacitive loads, parallel connection, proper analog wiring, and audio applications.

For More Information Write In No. 728

Tools for Automation, a full-color brochure from Advanced Micro Systems Inc., Nashua, NH, describes the company's **motion control and vision system products**. Featured items include intelligent integrated circuits and board-level controls; the MOTORvator series of motion controllers; drivers, motors, and power supplies; and cross-hair and icon video generators.

For More Information Write In No. 727

A capabilities brochure from Tekscan Inc., Boston, MA, describes its standard and custom **pressure sensors**. Incorporating patented pressure sensor technology, the sensors can be made as thin as .004" with scanning rates up to 200 kHz, ranges from 0 to 8000 PSI, and accuracy to ±5% of range. PC-based systems include sensors, connectors, interface boards, and software.

For More Information Write In No. 722

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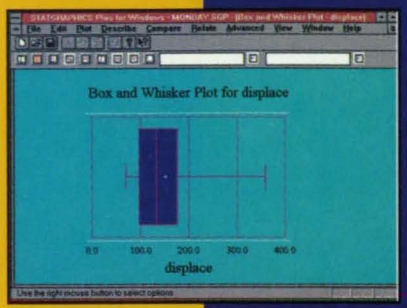

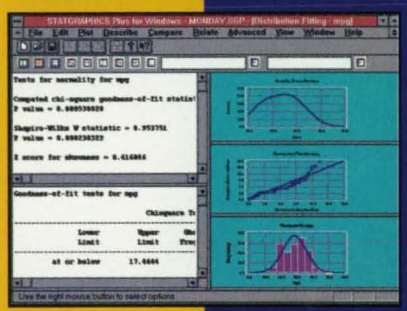

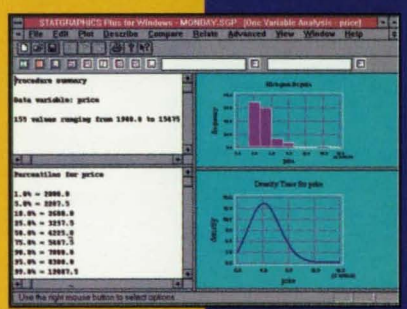

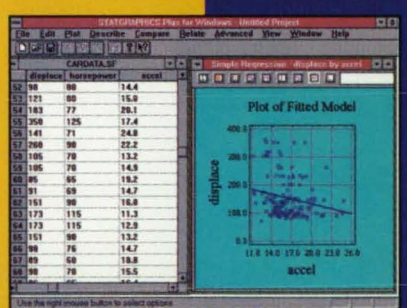

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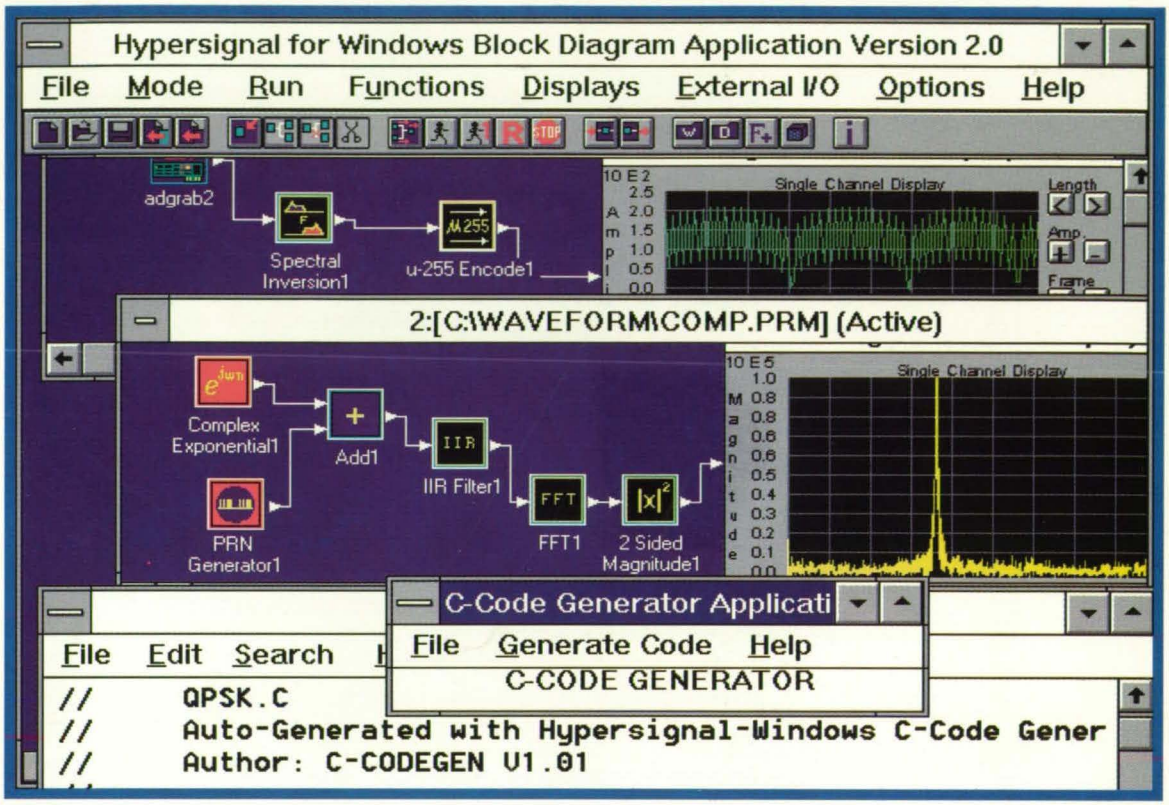

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